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TREATISE ON THE THEORY OF THE CONSTRUCTION OF HELICOIDAL OBLIQUE ARCHES.*

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PREFACE.

I have attempted in this treatise to attain two results:

First.—To supply our American engineering literature with a short, clear treatment of the construction of Helicoidal Oblique Arches; and,

Second.—To render simple all problems connected with their theory or construction. I especially hope that I may make the second plain to all who shall read these pages.

Long since I have been satisfied that much of the confusion and misunderstanding arising from the attempts to understand this subject, have arisen from the fact that authors have failed, either to state the fundamental principle, or to keep it constantly before the student's mind. Hence the general opinion has arisen, that helicoidal arches are of the most intricate construction, and too often their consideration has been abandoned with disgust.

The conception of a single principle will clear away all this misunderstanding. It is that of the process of the generation of helicoidal surfaces. It is a simple one, and, if constantly kept in mind, will render all other problems equally simple. No engineer's education is complete without a thorough knowledge of this subject. If the simple propositions of Chapter I. are mastered, there will be no trouble with the remainder of the treatise.

CHAPTER I.

ELEMENTARY PRINCIPLES.

1. A *helix* is a cylindrical curve that in passing over equal portions of the circumference of the cylinder, it travels over equal portions of the length of the cylinder.

2. Thus, in Fig. 1, A B C is the elevation of the semi-cylinder, A C D E, whose diameter is A C, and length is A E. Let A E also be the cylindrical length of the semi-helix, A D, whose elevation is A B C.

Divide A E and the circumference, A B C, each into the same number of parts of equal length, as shown in Fig. 1. Through the points, 1, 2, 3, &c., of A E draw lines parallel to A C, and through the corresponding points, 1′, 2′, 3′, &c., of A B C, draw lines parallel to A E. The intersections, 1″, 2″, 3″, are points, in the plan, of the semi-helix, A D.

Any number of points may thus be determined, and the curve of the semi-helix readily located, or drawn in the plan, Or, when the relation of the cylindrical length to the semi-circumference is constant, we can readily determine the equation of the curve, A D.

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3. If the cylindrical surface, A C D E, be straightened out into a plane surface, its width will evidently be equal to the semi-circumference, A B C, and its length will be equal to A E, whilst the semi-helix, by construction, would become a straight line on this surface. Therefore, in Fig. 1 draw A G equal to the semi-circumference, A B C, perpendicular to A E, and complete the rectangle, A E F G. This rectangle is called the *development* of the semi-cylindrical surface, A C D E, since it is its equivalent in plane surface. If we regard A C D E the inner surface or *soffit* of a right arch, A E F G is the development of the intrados, and the straight line, A F, is the development of the intradosal semi-helix, A D.

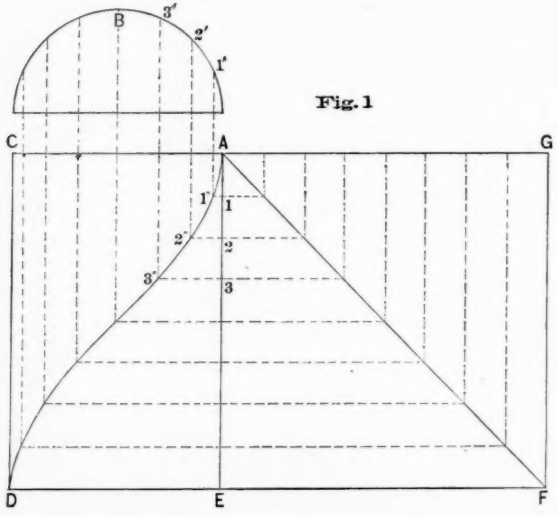


Fig. 1

4. From this we can determine the location in the plan of a semi-helix I J normal to A D at L (Fig. 2). Its development will evidently be also a straight line perpendicular to A F. Through L draw L M parallel to A G, intersecting A F at M, I M H drawn through M perpendicular to A F, is the development of the semi-helix normal to A D at L. Draw H J parallel to A G, then J and I will be the extremities of the normal semi-helix in plan, whose cylindrical length is I K, and elevation is A B C, whence we can determine the J L I in the same manner as A L D was determined. and as here shown.

5. In Fig. 3 H I J is the elevation, and H J K L the plan of the extrados or outer surface of a right arch of the depth I B, whose extradosal development is H L M N, wherein H N equal to the semi-circumference H I J is drawn perpendicular to H L, and L M and M N are respectively drawn parallel to H N and to H L.

The extradosal and intradosal developments are both made from the axis X X for the convenience of comparison of these surplan of the semi-extradosal helix H I J, faces and their lines. Here H P K is the whose cylindrical length H L is equal to H E of the semi-intradosal helix A P D. The curve H P K is determined from H L and H I J in the same manner as was A P D from A E and A B C. The straight line H O M is the development of H P K.

By construction P and O, the respective points of intersection of the curves H P K and A P D, and of the straight lines H O M and A O F are both on the line X X—X′X′, *i. e.* in plan and in development.

6. The surface included between the curves H P K and A P D is called the arch helicoidal surface, or arch helicoid, and a careful examination of Fig. 3 will

elucidate to us the fundamental principle of helicoidal arch analyses and construction. This fundamental principle is that of the process of the generation of this helicoidal warped surface.

7. All lines $1\,a-1'a'$, $2\,b-2'b'$, &c., are evidently elements of, and the only straight lines lying entirely within this warped surface, $1\,a$, $2\,b$, &c., are the actual lengths of $1\,a-1'a'$ of $2\,b-2'b'$, &c., since $1'a'$, $2'b'$, &c., produced are normal to the axis X X, or parallel to the right section of the arch. They are each equal to I B the depth of the arch as they are the portions of the radii $x\,1\,a : x\,2\,b$, &c., included between A B C and H I J.

8. Whence, when the right sections of the intrados and the extrados of an arch are circular arcs, we derive the following fundamental principle:

First. *A helicoidal surface is generated by a right line perpendicular to and moving on the axis as one directrix and on a helix as the other directrix, and the arch helicoid is that part of this surface generated by that portion of the generating line, equal to the depth of the arch, and included between the intrados and the extrados. The said generator of the arch helicoid is at all times perpendicular to the intradosal and extradosal helices of such helicoid.*

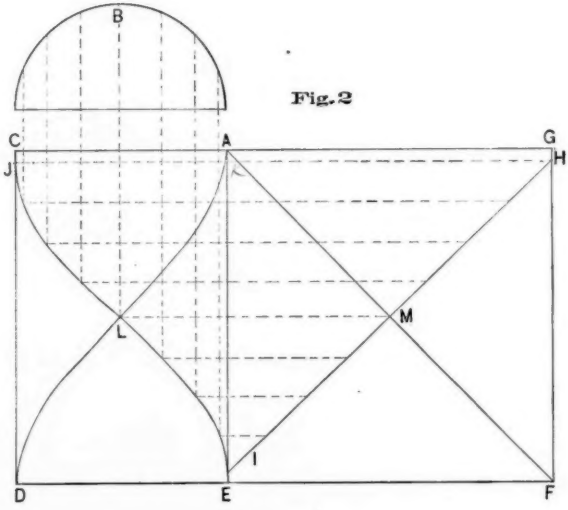


Fig. 2

Again the radii $x\,1\,a$, $x\,2\,b$, &c., at their points of contact in the intrados and in extrados, are perpendicular to these surfaces, and are perpendicular to all lines within these surfaces passing through these points of contact, and are therefore perpendicular to the helices passing through these points. In other words, any radius $x\,1\,a$ or $x\,2\,b$ drawn from the axis XX to either intradosal or extradosal helix, is at the point of contact with the helix perpendicular to it. From this it follows that the elements $1\,a-1'a'$; $2b-2'b'$, &c., are perpendicular, at the same time, to both the intradosal and extradosal helices A P D and H P K.

And as a corollary,

The intradosal and extradosal helices of an arch helicoid are parallel spiral curves whose perpendicular distances apart equal the depth of the arch.

9. These deductions are the essence of all problems connected with this subject. Nor should any one pursue it further without a thorough mastery of the principles here stated. A full understanding

of the process of the generation of helicoidal surfaces is of the first importance, and such a conception will render all further consideration of the elements of these warped surfaces clear and simple.

Chapter II.

HELICOIDAL CURVES AND TEMPLETS—TWIST RULES.

10. In the plan (Fig. 4) of the intradosal helix, make P S′ equal to P R′, and join R′ and S′ by a straight line, R′ S′, R′ S′ will, by construction, pass through P, R S will be its elevation. If, then, we lay off R″ S″ equal to and parallel to R′ S′, we can construct on it the curve of the intersection of a right vertical plane, R′ P S′, with the intrados, A C D E. It will be evident, by reference to the elevation, A B C, that the middle ordinate of R″ S″ at X will be X 4 equal to X B in elevation. Again, if at U and T in the elevation we draw perpendiculars to R S, these perpendiculars will respectively equal the ordinates V 3 and W 5 of R″ S″ at V and W. In this manner may be obtained any number of points, 3, 4, 5, &c., and the curve, S″, 3, 4, 5, &c., R″ constructed, which will be the curve of the intersection of the vertical plane, R′ S′, with the intrados, A C D E.

11. The corresponding extradosal elliptic curve, 6 7 8, may be similarly constructed, or both it and the intradosal curves may be determined for the equation of these elipses.

12. Let R″ R′ S′ S″ (Fig. 5) be the plan and S″, 3 4 5 R″ the elevation of a piece of timber of any thickness, R″ R′. On R″ R′ S′ S″ produce R′ P S′ of the plan of the helix in Fig. 4 at any convenient distance from, and parallel to, R′ P S′ draw the dotted line here shown. The space between R′ P S′ and the dotted parallel line will be the plan, and S″ 3 4 5 R″ the elevation of a templet of the intradosal helix, or the soffit cousing joint, R B S—R′ P S′.

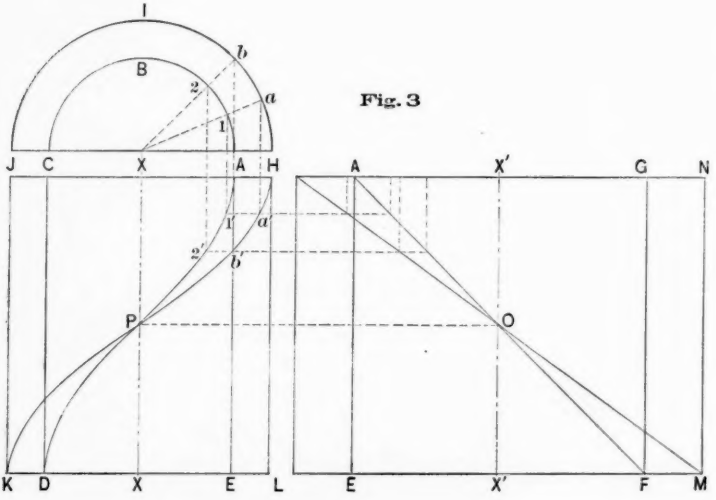


Fig. 3

In like manner the templet of the extradosal helix may be constructed. When any considerable portion of a helix is to be treated at one time this is the true way to construct the coursing joint templets.

TWIST RULES.

13. Let Fig. 6 be an enlarged drawing of the plan and development of the helices, A P D and H P K, between the point, P O, and the element, 1′ a′ (Fig. 3). It will be observed that the point, P, is the the plan of a vertical element of the arch helicoid, or the element at P is perpendicular to the horizontal plane. The element P and the point, 1′, of the intra-

dosal helix, locate the vertical plane passing through P and 1′, whose trace on the horizontal plane is P 1′3′. Then the line, $a'3'$, drawn from a' in the extradosal helix perpendicular to the vertical plane, P′ 1′ 3, is the measure of the warp of the arch helicoid at 1′ a'—1 a' from the plane, P 1′ 3′, for the given depth, I B, of the arch.

14. 1′ a' is, by construction, equal to I B and a' 3′ being perpendicular to the vertical plane, is perpendicular to any line within the vertical plane passing

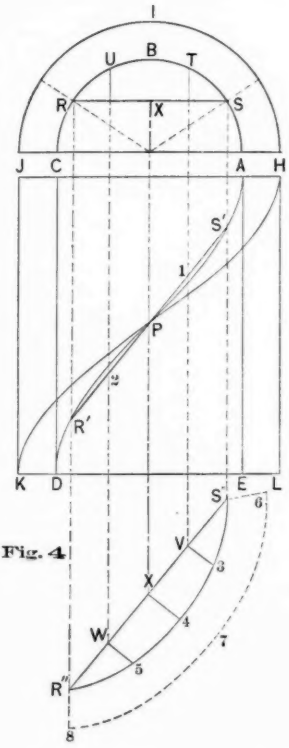


Fig. 4

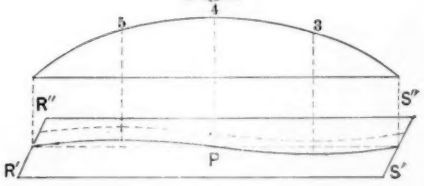
through its foot, 3′. Consequently a' 3′ is perpendicular to the line whose plan is 1′ 3′.

Therefore on the straight line, 4 5 (Fig. 7) erect the perpendicular, 5 6, equal to $a'3'$, and with 6 as a center, intersect 4 5 at 4 with an arch whose radius, 4 6, equals I B, the depth of the arch. 4 5 6 is the actual size of the wedge, 1′ 3′ a', in plan, that is perpendicular to the vertical plane, P 1′ 3′, and that supports the plane above the helicoid, P 1′ a' at 1′ a'. It should be noticed that 4 5 is the actual length of the line, 1′ 3′, in the plan or trace of the vertical plane.

15. To determine the warp of any element, 2′ b', from b' and from 2′ draw the perpendiculars, b' 7 and 2′ 8 to P 1′ 3′. Then on any line, 9 10, erect a perpendicular, 10 11, equal to b' 7, and lay of 10 13, equal to 2′ 8, and through 13 draw 12 13 parallel to 9 10. Then, with 11 as a center, intersect 12 13 at 12 with an arc of the radius, 11 12, equal to I B, and draw 9 12 parallel to 10 11. 9 10 11 12 will be the actual size of the truncated wedge shown in plan at 2′ b' 7 8, that is perpendicular to the vertical plane through P and 1′, and that supports this plane above the helicoid at 2′ b—2 b.

In same manner the warp of any element of the helicoid from the vertical plane, P 1′ 3′, may be obtained.

Fig. 5



16. The figures 4 5 6; 9 10 11 12, and a straight line, 14 15, equal to I B, are templets of the helicoid respectively at 1′ a'—1 a: 2′ b'—2 b, and at P—O, and in applying them care should be exercised that the lines 4 6 and 11 12 are applied to the helicoid with the points 4 and 12 exactly at 1′—1 and at 2′—2, and with the points 6 and 11 exactly at a'–a and at b'—b. The lines, 4 5 and 9 10 are, of course, to be brought exactly into the plane, P′ 1′ 3′, while the straight line, 14 15, will be applied at the intersection of the plane P 1′ 3′, and the helicoid at P—O. In practice, however, a straight line, 14 15, cannot be used. Therefore, draw 16 17 parallel to 14 15 = 15 16 and increase the depths of 4 5 6 and of 9 10 11 12 each a distance equal to 14 17 to the dotted line shown.

Then 16 17 and the dotted lines, 4 5 and 9 10, will be in a plane parallel to the

plane, P 1′ 3′, and these *parallel* and *twist rules* should, when applied, be always perpendicular to this parallel plane that they may ever be perpendicular to the first plane, P 1′ 3′.

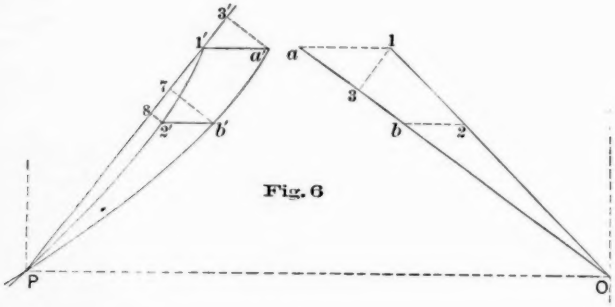


Fig. 6

The parallel and twist rules are all known as twist rules, as they are the templets by which the warp of the coursing beds are worked.

17. Fig. 8 is a perspective view showing the manner of applying the twist and parallel rules of Fig. 7. 15 11 6, is the extradosal helix whose exact length and

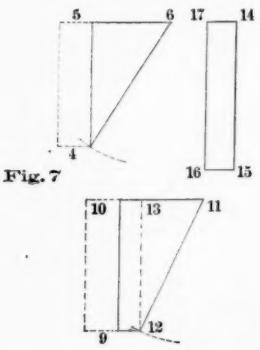
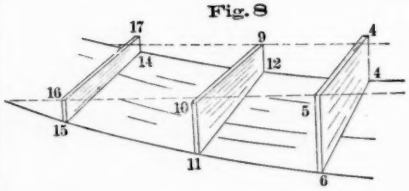


Fig. 7

that of its parts, 15 11 and 11 6, are taken from the development (Fig. 6), and are respectively equal to O *a*, O *b* and *b a*. 14 12 4 is the intradosal helix equal to 0, 1, and its parts 14, 12 and 12, 4 are equal to 02 and 21 (Fig. 6). The parallel and twist rules are of the same size and characteristics as in Fig. 7. Their upper edges 16 17, 9 10, and 4 5 lie in and coincide with the plane 4 5 16 17, to which these rules are perpendicular. The corners of the rules 6 11 and 15 are in the extradosal helix 6 11 15, while the corners 4 12 and 14 are in the intradosal. It will also be noticed that since the lower edges of these rules coincide with elements of the helicoid, they are and should be normal to the two helices of the helicoid.

18. We have here used in Fig. 8 three rules simply for the convenience of illustration. In practice, many may be used. Sometimes a parallel rule and a single twist rule will be all that are needed, and in fact this will generally be the case. The number of twist rules to be used depends upon the length and warp of the

Fig. 8



voussoir treated. However, enough of these should always be used to exactly determine the warped helicoids.

19. This method of determining the warped helicoids will overcome Professor Hyde's objection to the ordinary method of determining them, referred to in his book, "Skew Arches," pp. 11 and 12.

20. John Watson Buck in his treatise on this subject, "Essay on Oblique Bridges," pp. 13 and 14, presumes to determine the warp of the helicoids in the following manner: Let P 1′ *a*′ and

O 1 a (Fig. 9) be the plan and development a helicoid. From 1 in the development, draw 1 3′ perpendicular to O a. It is there stated that 1 3′ is the warp of the element 1′a′ from the plane P 1′ 3′. It has already been proven equal to a′ 3′. Therefore a′ 3′ would have to be equal to 1 3′. But by construction they are not equal. Hence it is that Buck's rule is not strictly true. But inasmuch as the length of the voussoirs are nearly always small in comparison to the whole length of the helix, this rule, though not theoretically true, is practically correct; for at the points P and O the curved lines 1′ 2′ P and a′ b′ P, and the straight lines 1 2 0 and a b 0 make the same included angles.

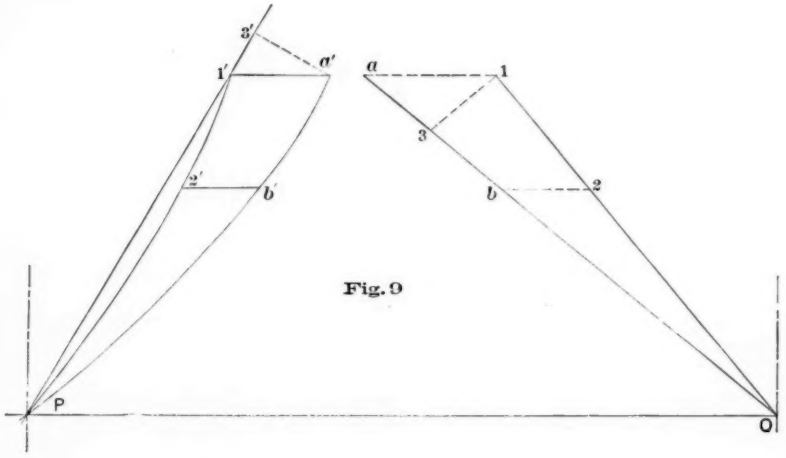


Fig. 9

But if warped helicoids of any magnitude are to be worked at one time, it would not be safe to use Buck's rule. The rule we have given is true for any length of the helicoid, and as easily obtained and applied as Buck's, and there is no reason why it should not be always used.

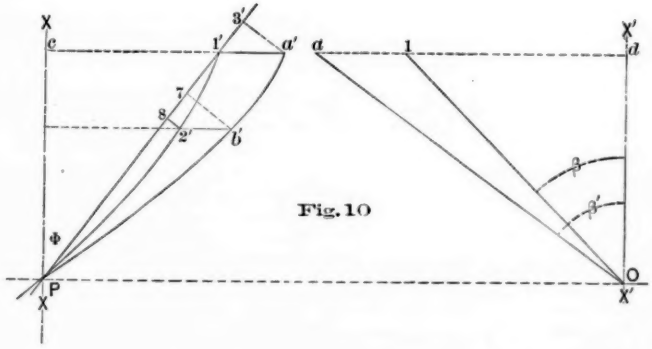


Fig. 10

21. Produce the lines 1′ a′ and 1 a (Fig, 10) to c and d in XX and X′X′

Let the β be *angle of the intrados*, 1 O d′; β′ be the *angle of the extrados* a O d′ (Fig. 10); Φ equal the angle 1′ P c

$=$angle $3'a'1'$ by construction; r the radius of the intrados and r' the radius of the extrados, $\frac{1\,d}{\pi r}=\frac{a\,d}{\pi r'}$.

Then

$$Pc=Od=O\,1\cos\beta=Oa\cos\beta' \quad (1)$$

$$1\,d=Od\tan.\,\beta \quad . \quad . \quad (2)$$

and

$$a\,d=Od\tan.\,\beta' \quad . \quad (3)$$

$$c\,1'=r\sin.\left(\frac{1\,d}{\pi r}\cdot 180^\circ\right) \quad . \quad . \quad (4)$$

$$ca'=r'\sin.\left(\frac{a\,d}{\pi r'}\cdot 180^\circ\right) \quad . \quad (5)$$

Whence we obtain

$$1'a=c\,a'-c1, \text{ and tang. } \Phi=\frac{'c\,1'}{P\,c}. \quad (6)$$

$$\therefore\ 3'a'=1'a\sin.\,\Phi \quad . \quad (7)$$

In like manner any warp distances $b'\,7$ and $2'\,8$ may be obtained.

KUTTER'S FORMULA.

By P. J. FLYNN, Mem. Tech. Soc.

Transactions of the Technical Society of the Pacific Coast.

Kutter's formula for feet measures is—

$$V=c\sqrt{r\,s} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

$$C=\frac{41.6+\frac{1.811}{n}+\frac{.00281}{s}}{1+\left(41.6+\frac{.00281}{s}\right)\frac{n}{\sqrt{r}}} \quad . \quad (2)$$

In this formula and in what follows:

V = velocity in feet per second.

C = coefficient of mean velocity.

S = fall of water surface (h), in any any distance (l), divided by that distance $=\frac{h}{l}=$ sine of slope.

R = hydraulic mean depth in feet = area of cross-section of pipe or conduit or channel in square feet divided by its wetted perimeter in lineal feet.

D = diameter of pipe or conduit.

N = the natural coefficient, the value of which depends on the nature and condition of the bed of the channel through which the water flows, or, in other words, its degree of roughness.

In that admirable and useful work, "Molesworth's Pocket Book of Engineering Formulæ, a modified form of Kutter's formula for pipe discharge is given, in which the value of

$$C=\frac{181+\frac{.00281}{s}}{1+.026\left(41.6+\frac{.00218}{s}\right)} \quad . \quad (3)$$

For facility of reference I will call this equation Molesworth's Kutter (3), and equation (2) Kutter's formula (2). No mention is made by Molesworth of the value of n, that is, as to whether the formula is intended to apply to pipes having a *rough* or a *smooth* inner surface. An investigation will, however, show that his formula is accurately applicable to *only one* diameter, that is, to a diameter of one foot, and with the value of $n=.013$.

The value of the term $\frac{n}{\sqrt{r}}$ in formula (2) is given by Molesworth in formula (3) as a *constant* quantity, whereas, in fact it is a *variable* quantity, its value, with the same value of n, changing with every change in the hydraulic mean radius or diameter of pipe.

Now, assuming the value of n taken by Molesworth to be $=.013$, and substituting this value for n in formula (2), we have

$$C=\frac{41.6+\frac{1.811}{.013}+\frac{.00281}{s}}{1+\left(41.6+\frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}}$$

and

$$\therefore C=\frac{181+\frac{.00281}{s}}{1+\left(41.6+\frac{.00281}{s}\right)\frac{.013}{\sqrt{r}}} \quad . \quad (4)$$

but by Molesworth's Kutter (3)

$$\frac{.013}{\sqrt{r}}=.026$$

$$\therefore \sqrt{r}=0.5$$

$$r=.25$$

and $d=1$

If we substitute in formula (4) for $\sqrt{r}$ its value 0.5, we have—

$$C=\frac{181+\frac{.00281}{s}}{1+.026\left(41.6+\frac{.00281}{s}\right)}$$

which is Molesworth's Kutter.

It is, therefore, apparent that no matter what the value of n may be, Molesworth's Kutter (3) does not give the same results as Kutter's formula, as it gives a *constant* coefficient of velocity, c, for all diameters having the same slope and the same value of n.

Kutter's formula (2) has certan peculiarities which are wanting in Molesworth's Kutter, and an investigation will show that Molesworth's Kutter differs materially from Kutter's formula, and that its application, except to one diameter, is sure to lead to serious error. I will briefly explain. In what follows $n=.013$.

1, By Kutter's formula (2) the value of c, or the velocity changes with every changes with every change in the value of r, s or n, and with the *same slope* and the same value of n, the value of c increases with the increase of r, that is, with the increase of diameter. It is on this variability of its coefficient to suit the different changes of slope, diameter and lining of channel that the accuracy of Kutter's formula depends.

By Molesworth's Kutter a change in the diameter, other things remaining the same, does not affect the value of c. With the same slope the value of c is *constant* for all diameters.

As an instance, with a slope of 1 in 1,000—

	6 Inches Diameter C=	20 Feet Diameter C=
By Kutter's formula (2)...	69.5	146.0
By Molesworth's Kutter (3)	85.3	85.3

It will thus be seen that the value of c by Kutter's formula (2) when $s=.001$, has a large range from 69.5 to 146, showing an increase of 111 per cent. from a diameter of 6 inches to a diameter of 20 feet. In this case, Molesworth's Kutter gives a *constant* coefficient of 85.3, and this coefficient applies to all diameters with a slope of 1 in 1,000.

It will be further found that Molesworth's formula gives the value of c, and, therefore, the value of the velocity and discharge, too high for diameters less than one foot, and too low for diameters above one foot, and the more the diameter differs from one foot the greater is the error. In these respects it follows the error of the old formulæ.

2. According to Kutter's formula (2) the value of c increases with the increase of slope for all diameters whose hydraulic mean depth is less than 3.281 feet—one meter—and with a hydraulic mean depth greater than 3.281 feet, an increase of slope gives a diminution in the value of c.

The small table herewith given shows this.

	12 Feet Diameter.		20 Feet Diameter.	
	1 in 1,000.	1 in 40.	1 in 1,000	1 in 40.
Molesworth's Kutter, $c=$.....	85.3	86.9	85.3	86.9
Kutter's formula, $c=$.....	137.7	137.9	146.0	145.7

It will be seen that by Kutter's formula, when $r=3$ feet, that is, less than 3.281 feet, an increase in the slope from 1 in 1,000 to 1 in 40 causes a slight increase in the coefficient, but when r is 5 feet, that is, more than 3.281 feet, the same increase in the slope causes a slight diminution in the value of c.

By Molesworth's Kutter, when $r=3$ feet an increase in the slope from 1 in 1,000 to 1 in 40 causes a greater proportional increase in the coefficient than Kutter gives, and when $r=5$ feet the value of the coefficient does not diminish with the increase of slope, but, on the contrary, it increases with the increase in slope, and its value is the same as when $r=3$ feet.

3. By Kutter's formula (2) when the hydraulic mean depth is equal to 3.281 feet (1 meter), the value of c is *constant* for all slopes, and is $=\frac{1.811}{n}$ which in this $=\frac{1.811}{.013}=139.31$.

Let $r=3.281$ feet, and, therefore, $\sqrt{r}=\sqrt{3.281}=1.811$, substitute this value in formula (2) for $\sqrt{r}$, and we have

$$C=\frac{41.6+\frac{1.811}{n}+\frac{.00281}{s}}{1+\left(41.6-\frac{.00281}{s}\right)\frac{n}{1.811}}$$

and

$$\therefore\ C=\frac{1.811}{n}$$ and when $n=0.13$,

$C=139\ 31$.

This is the only instance, I believe, where Kutter's formula (2) gives a *constant* coefficient with a change of slope. By Molesworth's Kutter, on the contrary, the value of c changes with every change of slope when $r=3.281$ feet.

It is evident that Molesworth's formula was adopted in order to simplify the application of Kutter's formula (2), but its simplification is of no practical use as it gives very inaccurate results. As shown above, with the exception of its application to one diameter, the formula is not Kutter's, although in appearance bearing a resemblance to it. However, a modification of Kutter's formula can be made, simpler in form than even Molesworth's Kutter, and giving results near enough for all practical purposes to those obtained by the use of the more complicated Kutter formula (2).

The value of C in Kutter's formula (2) with a slope of 1 in 1,000 and $n=.013$, is thus expressed:

$$C=\frac{41.6+\frac{1.811}{.013}+\frac{.00281}{.001}}{1+\left(41.6+\frac{00281}{.001}\right)\frac{.013}{\sqrt{r}}}$$

and

$$\therefore\ C=\frac{183.72}{1+44.41\times\frac{.013}{\sqrt{r}}} \qquad . \quad (5)$$

The following table will show the value of the coefficient c for several slopes and diameters according to formulæ:

	Molesworth's Kutter (3) C=	Kutter's Formula (2) C=	Formula (5) C=
6 inches diameter, slope 1 in 40	86.9	71.5	69.5
6 " " " 1 in 1000	85.3	69.5	69.5
4 feet " " 1 in 400	87.2	116.0	115.5
4 " " " 1 in 1000	85.3	116.5	116.5
8 " " " 1 in 700	85.8	130.5	130.5
8 " " " 1 in 2600	82.9	129 8	130.5

This table shows the close agreement of formula (5) with Kutter's formula (2), and it also shows the inaccurate results obtained by the use of Molesworth's Kutter (3).

The first column of this table shows that a formula with a *constant* value of $c=85$, that is,

$$V=85\sqrt{rs} \qquad . \quad . \quad . \quad (6)$$

will give results differing in an extreme case, only 2½ per cent. from Molesworth's Kutter, and in the greater number of cases, differing only about one per cent.

The second column of the table shows the wide range of the coefficient c, by Kutter's formula (2), from 69.5 to 130.5 to suit the different changes in the hydraulic mean depth and slope.

The objection to the old formulæ was that they gave velocities too high for small pipes and channels, and too low for large pipes and channels.

The following table will show that the same inaccurate results are obtained by the use of Molesworth's Kutter (3):

	Velocity in feet per second by		
	Molesworth (3).	Kutter (2).	Formula (5)
6 inches diameter, slope 1 in 40	4.86	4.00	3.89
6 " " " 1 in 1000	0.95	0.78	0.78
4 feet " " 1 in 400	4.36	5.85	5.83
4 " " " 1 in 1000	2.70	3.68	3.68
8 " " " 1 in 700	4.59	6.97	6.97
8 " " " 1 in 2500	2.30	3.60	3.62

This table shows that there is a wide difference between the velocities obtained by Molesworth's Kutter (3) and Kutter's formula (2), and it further shows that for the slopes usually adopted in practice for pipes, sewers, conduits, etc., that it is for slopes not flatter than two feet per mile, or 1 in 2640, formula (5) will give velocities that for all practical purposes may be considered almost identical with the velocities obtained by Kutter's formula (2). The difference is generally less than one per cent., and it seldom reaches three per cent.

Mr. L. D'A. Jackson, C. E., in his "Hydraulic Manual," and Mr. R. Herring, C. E., in a paper read before the Am. Soc. C. E., in 1878, extend the range of materials to which the different values of n adopted by Kutter apply.

A table of the value of n for different materials, compiled from Kutter, Jackson and Herring, is herewith given, and this value of n applies also in each instance to the surfaces of other materials, equally rough.

n=.009. Well planed timber, in perfect order and alignment; otherwise, perhaps .010 would be suitable.

n=.010. Plaster in pure cement; planed timber; glazed, coated or enameled stoneware and iron pipes; glazed surfaces of every sort in perfect order.

n=.011. Plaster in cement with one-third sand, in good condition; also, for iron, cement and terra cotta pipes, well jointed and in best order.

n=.012. Unplaned timber when perfectly continuous on the inside.

Flumes.

n=.013. Ashlar and well laid brickwork; ordinary metal; earthenware and stoneware pipe in good condition, but not new; cement and terra cotta pipe not well jointed nor in perfect order; plaster and planed wood in imperfect or inferior condition; and generally the materials mentioned with n=.010, when in imperfect or inferior condition.

n=.015. Second class or rough-faced brickwork; well dressed stonework; foul and slightly tuberculated iron; cement and terra cotta pipes with imperfect joints and in bad order; and canvas lining on wooden frames.

n=.017. Brickwork, ashlar and stoneware in an inferior condition; tuberculated iron pipes; rubble in

cement or plaster, in good order; fine gravel, well rammed, $\frac{1}{3}$ to $\frac{2}{3}$ inches diameter; and generally the materials mentioned with $n=.013$ when in bad order and condition.

$n=.020$. Rubble in cement, in an inferior condition; coarse rubble, rough set, in a normal condition, coarse rubble, set dry; ruined brickwork and masonry; coarse gravel, well rammed, from 1 to $1\frac{1}{3}$ inches diameter; canals with beds and banks of very firm, regular gravel carefully trimmed and punned in defective places; rough rubble; with bed partially covered with silt and mud; rectangular wooden troughs with battens on the inside two inches apart.

$n=.0225$. Coarse, dry-set rubble in bad condition.

The accuracy of the results by Kutter's formula depends on the proper selection of the value of n for the surface of the material over which the water flows.

Again referring to the simplified form of Kutter's formula (5); if, in this equation, we call the numerator on the right hand side of the equation K for any value of n we have

$$C=\frac{K}{1+44.41\times\frac{n}{\sqrt{rs}}}$$

and

$$V=\left\{\frac{K}{1+44.41\times\frac{n}{\sqrt{r}}}\right\}\sqrt{rs} \quad . \quad (7)$$

In the following table the value of K is given for the several values of n already referred to.

n.	K.	n.	K.
.009	245.63	.015	165.14
.010	225.51	.017	150.94
.011	209.05	.020	134 96
.012	195.33	.0225	124.90
.013	183.72		

If, therefore, in the application of formula (7), within the limits of n as given in the table, and within the limits of slope of 1 in 2640 as already explained, we substitute for n and K their values found on the same line in table, and also the value of $\sqrt{r}$ we have a simplified form of Kutter's formula.

For instance, when $n=.011$ and D=2 feet, we have

$$V=\left\{\frac{209.05}{1+\left(44.41\times\frac{.011}{.707}\right)}\right\}\times\sqrt{rs} \quad (8)$$

TABLE GIVING VALUE OF $\sqrt{r}$.

Diameter. Feet.	Inches.	$\sqrt{r}$.	Diameter. Feet.	Inches.	$\sqrt{r}$.
0	5	0.323	2	6	0.790
0	6	0.354	2	9	0.829
0	7	0.382	3	0	0.866
0	8	0.408	3	3	0.901
0	9	0.433	3	6	0.935
0	10	0.456	3	9	0.968
0	11	0 479	4	0	1.000
1	0	0.500	4	3	1.031
1	1	0 520	4	6	1.061
1	2	0.540	4	9	1.089
1	3	0.559	5	0	1.118
1	4	0.577	5	3	1.146
1	5	0.595	5	6	1.173
1	6	0.612	5	9	1.199
1	7	0.629	6	0	1.225
1	8	0.646	6	6	1.275
1	9	0.661	7	0	1.323
1	10	0.677	7	6	1.369
1	11	0.692	8	0	1.414
2	0	0.707	9	0	1.500
2	1	0.722	10	0	1.581
2	2	0.736	11	0	1.658
2	3	0.750	12	0	1.732
2	4	0.764	13	0	1.803
2	5	0 777	14	0	1.871

To prevent possible difficulties on the waterway through a lack of water in the summer months, the Leeds and Liverpool Canal Company has constructed a storage reservoir to hold a hundred million gallons of water, at Barrowford, near Colne, for the benefit of the Lancashire portion of the system, and is building another at Winterburn, near Skipton, which is to have a capacity for three hundred million gallons, for the protection of Yorkshire interests on the canal.

UNAPPROVED ARMOR-CLADS.

From "The Engineer."

One of those awkward things designated "an open secret" has lately appeared with regard to the projected armor-clads the Trafalgar and the Nile. These two ships, the construction of which is just being commenced, will be the largest ships in the British Navy, and will each cost, with her armament, a million sterling. It might be supposed that the construction of these enormous and costly vessels would not be entered upon without the most careful consideration of everything which can appertain to their efficiency as engines of war. Larger than the Inflexible—though not to any marked extent—these ships might be expected to embody, in their structure and equipment, the most advanced ideas as to offensive and defensive power. In nothing ought these ships to fall behind their competitors, whether at home or abroad. Yet on the very threshold of this affair we are met with the astounding statement that the design on which these two sister ships are to be constructed is *minus* the approval of the late Director of Naval Construction, Sir N. Barnaby, and also of that gentleman's successor, Mr. W. H. White. Neither of these eminent naval architects identifies his reputation with these coming armor-clads. Neither one nor the other designed them, and we believe we are right in saying that the opposition of Sir N. Barnaby to the construction of these ships was and is of a very emphatic character. With regard to Mr. White, it may be sufficient to say that he simply withholds his concurrence from the proposal to build ships of such a type. The question arises, therefore—Who designed these ships? Not only so, but who is to be held responsible for them when they are finished? The design could not have dropped from the clouds; but we fear that the responsibility concerning it is of a very hazy description. We need not suppose that the design is actually bad *per se*. It is sufficient to fear that it is bad relatively. A Lord Mayor's coach might be very admirably planned and properly built, but it would be a very poor substitute for a locomotive. This is the kind of objection which applies to the Nile and Trafalgar. They may be very good ships in themselves, but the British Navy wants something else. As the most costly and largest ships in the whole fleet, they ought not merely to exhibit superiority to the other ships of the navy, but they ought to show the maximum effect producible from the expenditure that is to be devoted to them. In this they will infallibly fail, and their inception is marked by absurdity, as falling dismally short of what is required of the latest and most costly of British iron-clads.

We shall doubtless be asked for the particulars on which this indictment is founded. First, with regard to the armor. It is said that these ships are to have steel-faced armor 20 inches thick. This is no great achievement, seeing that the Inflexible has armor of 24 inches. The latter, being of iron, is probably inferior to the steel-faced plates of the new ships. But why not retain the thickness of two feet as a maximum, and couple with this the increased resisting power due to the face of steel? The 110-ton guns of the Italian Navy have penetrated 19 inches of steel-faced armor, so strongly backed that we may rest assured the 20 inches on the Trafalgar or the Nile would yield to the blow. But this does not end the story. The armor is not 20 inches everywhere. A concession has been made to Sir Edward Reed by lengthening the belt along the water-line, with the inevitable result of thinning the armor upon the citadel. As a consequence, the heart of the ship is accessible to the enemy's fire. It is putting armor upon a man's legs and thinning the breastplate. The man may save his shins and get his heart pierced. After all, the belt does not extend the whole length of the ship, at least one-third of the water-line being left without this defence, the sole protection there being the under-water armored deck, for which Sir E. Reed generally expresses such profound contempt. From a consideration of the armor we may proceed to a survey of the guns. Here,

indeed, we witness a falling off of a most extraordinary character. The Inflexible carries her four guns of 80 tons each. But these two armor-clads, embodying somebody's latest ideas, are to have nothing heavier than breech-loaders of 66 or 68 tons, four being in each ship, carried in two turrets. That these guns are more powerful than those of the Inflexible is no answer to the objection that they are not so powerful as they ought to be. How do they stand in comparison with the 110-ton guns of the Italian fleet? Even our own Benbow, one of the despised "Admiral" class, will carry a couple of 110-ton guns. Again, in the element of speed what do we find? The projected rate is 16 knots. An attempt is made to get up a belief that the speed will be 18 knots. But this is mere conjecture, and when we remember that the practice now is to make the contractor specifically undertake the highest practicable speed, or very nearly so, there is no reason to expect that the coming ships will exceed the proposed rate by any important amount. Perhaps half a knot more may be looked for, but nothing further is probable. That the wish should be father to the thought concerning this higher rate of speed is readily accounted for. The Italia, just about to commence her steam trials, is expected to realize 18 knots, and anything less from the British ships would be intolerable. Commenced eight or nine years ago, the Italian monsters, Italia and Lepanto, took their start in a period when there was less light on the armor-clad question than now exists. The year 1886 is not as 1877 or 1878, so far as naval armaments are concerned. We do not say that a ship of 12,000 tons displacement can be reasonably expected to vie upon all points with one of 13,500, but assuredly she ought not to lag so far behind as to carry guns of 68 tons instead of 110 tons, and to have a speed of 16 knots as opposed to 18, with armor somewhat thinner than that of the foreigner.

We grant that the armor-clad question is one of great difficulty. So it has been from the first; but more especially now. The difficulty culminates at last in a conflict of opinion between the Board of Admiralty and its technical advisers. It may be said that the question is rather one of policy than of naval architecture. To a certain extent this may be true, yet one element overlaps the other in a manner which renders a complete severance impossible. Sir N. Barnaby does not absolutely object to armor-clads, neither does Mr. W. H. White. But seeing that we have a certain number of iron-clads already in the navy, the question arises as to what is the real need of the present hour. The two authorities just named are perhaps better able to estimate the merits and defects of different classes of ships than the usual members of a Board of Admiralty. Minds technically trained may be supposed to discern with peculiar readiness the weak points in a ship of given design. The defects which now beset the armor-clads are doubtless realized with peculiar keenness by those who have most to do with the introduction of such ships. If ever there was need for a Committee of Inquiry into this matter, it is now. Some years ago we had a Committee on Designs for Ships-of-War. Such a committee need be appointed again, and there is this happy feature with regard to the suggestion, that it has the support both of Sir E. Reed and Mr. W. H. White, while to these names may be doubtless added that of Sir N. Barnaby. In the current number of *Harper's Magazine* Sir E Reed has an article on "The British Navy," which partially revives the old controversy concerning the Inflexible, and reiterates to the full the furious criticisms put forth by the writer in his letters to the *Times* with regard to the "Admiral" class of armor-clads as well as other ships. Sir Edward declares that the "whole series of so-called first-class iron-clads, of which only about one-third of the length has been protected by armor, are quite unfit to take a place in any European line of battle." The present condition of the British Navy is spoken of as "deplorable." One cause of this degeneracy is said to be the sustained attempt of successive Governments to keep the naval expenditure within or near to a fixed annual amount. Hence, the size and cost of our first-class ships have been cut down to suit a financial pressure. Of course, this argument makes no reflection on the naval architects concerned in designing the ships in question. But Sir E. Reed complains that another source of mischief has consisted in reducing the

extent of armor carried by the principal vessels, rendering them, in his opinion, quite unfit to take part, with any reasonable hope of success, in any general engagement. Certain ships which the authorities consider to be armored Sir E. Reed refuses to recognize as such, and in this way as many as a dozen are struck off the list, namely, the Ajax, Agamemnon, Anson, Benbow, Camperdown, Collingwood, Colossus, Edinburgh, Howe, Rodney, Imperieuse, and Warspite. To this there is an addition of two ships of 10,400 tons displacement, with 18-inch armor, and five cruisers of 5,000 tons displacent, with 10-inch armor, recently ordered by the Admiralty to be built by contract. The objection to these ships is that, although they have some armor on their sides, "they are liable to capsize at sea from injuries inflicted on their unarmored parts." The Inflexible is omitted from the list, "out of compassion for those officers of the Admiralty who have long ago repented those trying compromises with conscience, by aid of which they expressed some slight confidence in her ability to float upright with her unarmored ends badly damaged." With this sarcastic stroke, Sir E. Reed intimates that, although his condemnation of the Inflexible has been refuted by a thoroughly qualified tribunal, he is "of the same opinion still."

That Sir E. Reed should be thus disposed to criticise ships which do not represent his own ideas, is, of course, to be expected. But to this we have now to add that two responsible advisers of the Admiralty are far from satisfied with certain recent designs. Sir N. Barnaby is free now to say what he likes, but the question is not merely one between himself and Sir E. Reed. These two authorities may controvert each other to any extent, but the interest of the public lies in knowing what is the real state of the Navy, and what are the prospects for the future. If our ships are defective, as Sir E. Reed declares, the fact should be placed beyond the reach of controversy. If the attack is unreasonable and groundless, let the public mind be reassured. If the coming Nile and Trafalgar, though uncondemned by Sir E. Reed, are not what they ought to be, let the design be altered while alteration is practicable. A properly constituted committee to investigate all these points is the need of the hour. If such a committee should be appointed—as we trust will be the case—one result, we expect, will be this, that they will advise caution in laying down any more armor-clads. But if such a committee is to be of any service, it must be more expeditious in doing its work, and more unanimous in its verdict than committees of the kind have been heretofore. Better no committee at all than one which will merely serve as an excuse to baffle inquiry.

THE CAUSE OF EROSION IN THE BORE OF GUNS.

By Captain A LAUFROY, of the Marine Artillery.

From Abstracts of the Institution of Civil Engineers.

The author commences with a proposition already enunciated in several works on ballistics, viz., "That the erosion of the bore of a gun results from the escape of the powder-gases at high tension through narrow orifices, such as the vent or windage of the projectile." The essay is divided into six chapters. (1 and 2) Historical, deal with smooth-bore guns, guns with few grooves, and the modern polygroove rifling. After citing numerous experiments with various pieces of the above description, the author concludes on the polygroove system as follows:—viz., "That erosion always commences in the upper parts of the bore, and is divided into two distinct zones separated by an interval less attacked." The first zone is in the forward part of the cone of the powder-chamber, and often embraces the origin of the grooves. The second, which is always the most important after a prolonged firing, is at a distance from the commencement of the rifling, greater as the powder is more progressive. The lands are always less attacked than the neighboring grooves, sometimes they are intact. In time, the

erosion extends over the circumference of the bore, at the positions of the two zones, but the top is always most injured. Other things being equal, the erosion develops as much more rapidly as the calibre is greater, and more quickly in bronze than in steel. Tool-marks or defects in metal in the upper part only of the powder-chamber are increased rapid ly. After prolonged firing, an increase in the diameter of the bore is found chiefly in the shot-chamber, where the greatest erosion occurs. At the same time the ring of the projectile advances further up the cone, joining the powder-chamber to the bore.

The length of service of a gun is almost always limited by the loss of velocity and accuracy occasioned by erosion.

The wear of the rings, almost nothing at the commencement of firing, increases with the service of the gun.

For the first round of each series in a gun, the wear of the ring is about double that of the succeeding rounds (Report 826, 1879).

Chapter III. is a theoretical study of the mode of production of erosion in the bores of guns made since 1870.

The author states that when a gun is fired, it expands under the action of the powder-gas, which exerts a certain tension on the interior of the bore in a circular sense. When the gun is in one piece, this expansion of the bore is proportional to the calibre and interior pressure; according to the formula of General Virgile it is in inverse ratio of the modulus of elasticity, and diminishes when the thickness of the tube increases.

But large guns are composed of several pieces, which, if they have the same modulus of elasticity, require a fresh formula to express the relations of the circular tension and interior pressure on the bore, owing to the shrinkage employed to build up the gun. This formula is given, and the author, with the object of proving that the erosion commences in the upper part of the bore at the point occupied by the driving ring of the projectile when the maximum pressure occurs, and that all things being equal, it is greater as the calibre increases, proceeds to consider the ring of the projectile in three positions in the bore: (1) In the forward part of the cone at the commencement of the bore. (2) A little to the rear of the last position. (3) At the rear of the cone—the gun being taken as a smooth-bore, with the powder-chamber larger than the bore, and connected with it by a cone.

The second zone of erosion is next dealt with, this being a consequence of the first. The theory that the principal zone is caused by blows from the projectile, is questioned, as in this case the lands should suffer most, whereas it is the grooves that are most injured; it is not denied that blows are given by the projectile, but it is suggested that these will be reduced, as also the escape of gas, by increased forcing of the rotating rings. In considering the wear of the driving rings, on the hypothesis that the walls of the gun act as a file, for helicoid rifling the author gives a formula showing the wear to be proportional to the tangent of the final inclination of the grooves and the square of the initial velocity, and considers it advantageous to increase the number of the grooves. To diminish the wear as much as possible, and to preserve the ballistic properties of the gun, the author suggests a parabolic form of rifling, in which the pressure will be little at the commencement of movement, that is, at the parts most eroded; but in choosing a form of rifling, the wear, and also the maximum circular pressure exerted by the lands on the ring, must be taken into account.

Suggesting an interior design for a gun, the author adopts for the shot-chamber a cone sufficiently long for the ring to be tightly in contact at the moment of maximum pressure. The angle of this cone has been approximately determined by experiment, the length should be a little more than the distance, which in guns of the same calibre already proved, separates the initial position of the driving-ring and the mass of the erosion. The suggested modifications entail an increase in the diameter of the fillet of the driving-ring, which must be fixed by experiment.

The simplest solution from the manufacturing point of view consists in making a second cone to follow the cone of supports for the ring of a projectile, this cone having a greater inclination, the commencement of the grooves being well in advance of the driving-ring of the projectile when sent home.

SOME POINTS IN ELECTRICAL DISTRIBUTION.

By Professor GEORGE FORBES.

From the "Journal of the Society of Arts."

When I had the honor, just a year ago, to give a course of Cantor Lectures to this Society, on the distribution of electricity, the subject had not till then been treated in a systematic manner. I had then occasion to speak in strong terms of the methods habitually adopted, and subsequent experience has confirmed me in the justness of my criticisms. I gave a fairly complete account of the practical systems of laying electric mains which were at the disposal of the engineer when designing a system of distribution; but in the course of only three lectures it was impossible to do justice equally to all systems. When I was this year asked to read a paper before the Society, I eagerly availed myself of the opportunity to take up the straggling threads, and say a few words on the subjects which were previously but inadequately treated.

Allow me to remind you that, in my lectures, I described five different ways of laying the mains, each one depending upon a different method of connecting the dynamo machines and lamps. Three of these may be called direct systems, and two indirect. Each system has special advantages when applied to suitable cases, and when an engineer is designing a scheme of distribution he carefully considers the *pros* and *cons* of each system as applied to the special case, and very often he has to go through the whole calculations of the scheme according to several different systems. And here let me repeat, what I have often stated before, that no amount of labor and expense in these preliminary calculations should be grudged, as the ultimate saving effected by the careful selection of a suitable and economical system may easily range to 50 per cent. or more on the total cost of the installation.

The three direct systems are the parallel, series, and parallel-series methods of attaching lamps to the main conductors.* The two indirect systems are with the use of secondary batteries and secondary generators. Each of these systems is capable of being varied in the details of its application, and each is specially applicable to particular cases.

In a parallel system, each lamp is attached by wires to the two main conductors, and thus to the two terminals of the dynamo. This is its characteristic feature, viz., that the lamps are all metallically connected with the terminals of the machines.

In the series system, the conductor going through the district has its two ends connected one to each pole of the dynamo. But wherever there is a lamp the conductor is severed, and each terminal of the lamp is attached to one of the severed ends.

In the parallel-series arrangement the district is divided into sections. The first section and the last section have each a conductor attached to one terminal of the dynamo. The other conductor of the first section extends also through the second section, but no farther. Another conductor extends through the second and third sections, another through the third and fourth, and so on. In each section the two wires from each lamp are attached to the two conductors of that section.

The first, or parallel system, is generally most suitable for small installations, but the cost of conductors becomes extravagant when the area is extended, except in very special cases. The series system is at present only used for arc lights, sometimes with the insertion of a few glow lamps in parallel to replace an arc lamp.

The third system is admirably suited in every case where the number of lamps in use at any time is constant, and may perhaps be modified so as to be applicable to other cases. Smaller conductors can be used on this system than on the first, and this effects a very great economy.

* In my Cantor Lectures I used the terms multiple arc, series, and multiple series. I prefer the terms now advocated.

Having recalled these points to your notice, I need say no more, as I treated these three systems and their modifications very fully in my Cantor Lectures.

I thought I had spoken strongly enough about the enormous cost of the main conductors, and the necessity for selecting that size of conductor which is the most economical. We must not use too small a conductor, for then the waste of energy in heating the conductors would be enormous. Nor must we use too large a conductor, for this means buried capital. We must select that size which balances one cause of loss against the other, so as to give the maximum economy.

I find, however, that, while this axiom has been accepted as such in this country, some writers from America still try to uphold the fallacious views which have hitherto been in vogue here. I have noticed more than one criticism from America, by people asserting themselves to be connected in some way with some of the Edison companies, who protest against my statement that the three-wire system effects an economy of copper of only 25 per cent. over a two-wire system. The difference between us is that I start with the *axiom* that we are to use the most economical size of conductor. My critics start with the *assumption* that they shall use a conductor which shall waste exactly 10 per cent. of the energy. In this way they use a conductor which is not the most economical, and they show a saving of $62\frac{1}{2}$ per cent. of copper over the two-wire system, but with a possible extra waste of energy of $62\frac{1}{2}$ per cent. I said in my Cantor Lectures, and I repeat it this evening, that the manipulation of figures may suit American financiers, but it is not electrical engineering.

Before proceeding to discuss the indirect methods of distributing electricity, which is the main point I wish to touch upon to-night, I wish to supplement my remarks on series lighting by a statement of what has been done in the last year. I expressed a hope that more attention might be given to the lighting of houses by glow lamps in series. I further showed that it was only by means of a constant current flowing through glow lamps in series that the regulation of each lamp could possibly be effected on economical principles. This regulation must be accomplished by altering the length of the filament in the lamp. This has never yet been done, but if inventors once realize the importance of the object to be attained, I feel sure that we shall not have long to wait for the solution of the problem. Now I am delighted to be able to inform you that during the past year at least one inventor has been applying himself to the placing of glow lamps in series. Mr. Bernstein, who has paid so much attention to the system of glow lamps, has worked out the problem of using lamps of low pressure and large current in series. He has boldly taken extreme measures, and proposes to use lamps of 6 volts and 10 ampères. And here he has got over a difficulty I referred to in my Cantor Lectures. I said that there was no economical way of preventing a broken lamp from extinguishing all the others on the series. Passing part of the current through a shunt whose resistance is 100 times that of the lamp would be very expensive if we had in use lamps of the ordinary type, but with a lamp whose resistance is a fraction of an ohm, the expense would be trifling. When the lamp breaks, the current in the shunt is increased so as to release a contact which short-circuits both the lamp and the shunt.

I still think, however, that the loss of energy by heat conduction at the terminals may be very great in lamps of so low a resistance; Mr. Bernstein tells me it is ten per cent. Still I can well foresee that, even if a very sensible loss of energy occurred, the economy and convenience of using such a system might be amply sufficient to warrant its adoption in many cases.

I congratulate Mr. Bernstein on his work in the past, and would urge him to develop this idea more fully, and I can assure him that I, for one, will give the fullest consideration to the system when preparing the plans for electric light installations.

I should like also to take this opportunity of congratulating other makers of electrical appliances on the advances which have been made since the date of my Cantor Lectures. I should like especially to congratulate Mr. Swan on the improvements he has made in the manufacture of glow lamps; the Messrs. Siemens

and Messrs. Crompton on their successful construction of very large dynamos; Messrs. Elwell and Parker on their great improvements in the details of construction of dynamos and motors; and the Electrical Power and Storage Company on the continued improvements in their secondary batteries. I would equally congratulate Messrs. Willans and Crompton for the continued improvements in steam-engine governors, for keeping the current from a dynamo or the pressure at any point in the circuit constant; likewise Mr. Ferranti for having brought out an electric current meter which promises to fulfil all the wants of engineers and the public in this direction; and last, but by no means least, Messrs. Woodhouse and Rawson for various new devices which will go far to assist in designing and carrying out many schemes of lighting; and I would specially mention their automatic cut-out, adjustable to any strength of current, which, though not so new as some other devices, has only been brought prominently to my notice during the past year, and whose simplicity and reliability give me great confidence in employing it. I must not fail to include here, as a subject for congratulation, the rising esteem in which secondary generators are held, and the improvements which have been made in their manufacture.

When I add to this list the admirable lamp-holder of Mr. Alfred Swan, Varley's adjustable carbon resistances, and other small but useful accessories, I think you will agree with me that the facilities at the disposal of the engineer for designing a satisfactory scheme of electric lighting, and which have been added to his store during the past year, are very abundant.

About one of these appliances I should like to add a few words:

First, I may say that the Electric Lighting Act was rendered abortive, if for no other reason, simply for the want of an electric-current meter which was in all points satisfactory. In the year 1882, a patent was taken out for a meter in which the current passing round an electro-magnet created a field where mercury was placed, which rotated when the current passed through the mercury from the center to the exterior of the field. If the magnetism be proportional to the current and the friction be proportional to the square of the velocity, then the number of turns completed in any time is a direct measure of the total quantity of electricity which has flowed through the meter in that time. The marked improvements introduced into this meter by Mr. Ferranti consist in the perfection of the magnetic circuit, and the introduction of an almost frictionless mechanism for correcting the revolutions, and showing them on dials like a gas-meter.

I have many of these appliances on the table, which any members of the audience may examine at the conclusion of the paper.

In referring to my Cantor lectures, let me make a few remarks about a double table which I introduced to assist engineers in calculating the size of mains required in any installation. These tables have been copied into a number of technical journals and books of reference, but in nearly every case there is no word of explanation how to use them. I have found these tables of such paramount convenience, that I think it right to call attention to them once more. The economical size of main depends upon three variable factors—the price of laying down a ton of copper mains, the interest to be charged on the capital sunk in mains, and the value of an electrical horse-power for the number of hours that it is to be utilized during the year. My table is divided into two parts. Look along the line in the second part, which relates to the percentage on capital which you propose to use, until you come to the column relating to that price of copper which you propose to use, and you then find a number printed which we may call the auxiliary number. Now take the first part of the table and look along the line which relates to that value of a year-horse-power which you propose to use, until you find the auxiliary number; the heading of that column of figures tells you the size of main per 1,000 ampères which is most economical to use according to the data you have employed.

I will now remind you of the position in which we were left after a full discussion in the Cantor Lectures of the three direct systems of distribution. The parallel system, or the three-wire system, is admirably adapted in cases where the farthest lamp of the district is within

two hundred yards of the central station. So soon as you go to greater distances, the cost begins to increase in an alarming ratio. Hence this system would be applicable to a large district only by having engines and dynamos put down at a very large number of small stations. Now, a station is not worked economically unless the engine-driver and stoker are fully employed, and the maximum economy cannot be reached with less than about 1,000 horse-power. Thus, the parallel system is only applicable to cities so densely populated as to have a consumption of about 10,000 16-candle power lamps in a radius of two hundred yards. But in most districts of this class space is valuable, and a large number of such stations would be very expensive. We must then, in the parallel system of distribution, be content to work at a cost which is above that of the ideal of economy. There are many cases where the great simplicity of such a system does actually make it worth while to sacrifice this ideal of economy, and when an engineer is consulted on such matters, it is his duty to estimate the exact loss from not strictly following the ideal economical rules before adopting or rejecting this system. In order to make a parallel system effective, the central station must use distributing boxes, the methods of placing which are described in my Cantor Lectures.

The cure for all these evils would be found if a thoroughly satisfactory system on the parallel-series plan were known. In that case, high tension electricity might be used, involving smaller conductors. Thus, the central station might be at a distance, where land is cheap, and it might be of any size, so that all the works would be in the same place, as they are in gas distribution. Here the only departure from the ideal of economy lies in the length of the conductors to the district which has the supply. But these conductors are comparatively small, and no engineer would recommend the adoption of such a system unless he found that the economy of having the works out of the expensive district counterbalanced the extra expense in mains.

Now I regret to be compelled to say that, after discussing all the ingenious plans on the parallel-series system proposed by Mr. Edison and others, I arrived at the conclusion that at this time there is no parallel-series system of distribution which is quite satisfactory. I do not say that such a system cannot be devised, but I do say that at this moment no such system is available to the electrical engineer, except in the case where the same quantity of electrical energy is consumed in any district at all hours during which the current is being used. There are some cases where it will pay to insert equivalent resistances when lamps are put out. These cases are rare, but they must not be lost sight of by the engineer.

Having in the Cantor Lectures discussed all the direct systems of distribution, I will complete my outline of this part of the engineer's profession by an examination of the two indirect methods which I formerly touched upon only lightly, viz., secondary batteries and secondary generators.

Secondary Batteries.

During the electric boom (as Americans would call it) of 1882, the secondary battery took a prominent part, not so much for what it had done as from what was expected it would. It was said that since no one would think of sending gas from the retorts without storing it in a gasholder, so the same must be done with electricity. Every one will admit that it is most desirable that this should be done, and I am glad to say that secondary batteries have been improved to such an extent that there is every reason to hope that this will be done, always provided that the companies who supply them, do not expect the public to repay them for the hundreds of thousands of pounds which may have been thrown away in the past.

I have been given to test about a dozen different kinds of secondary batteries, of which I have found some four or five to be good, and the others mostly worthless. I can say this, that at the present moment secondary batteries can be supplied by certain makers which are to be relied on with careful usage, and which give us 70 to 80 per cent. return for the energy expended.

Now, it might be asked, what are the advantages of storing the energy if you lose 25 per cent. by doing so? The first advantage is that a breakdown in the ma-

chinery does not then interfere with the supply. The second advantage is that the steadiness of the supply does not depend upon the speed of moving machinery. The third and great economical advantage is that your expensive engines and dynamos are paying interest twenty-four hours of the day, instead of only a few hours, by doing their work, and a smaller supply of engines and dynamos suffices.

Now, this is all very well, so far as having secondary batteries at the point of supply is concerned, but it does not help us much so far in the great problem which we have attacked, viz., that of electrical distribution. But the improvement of secondary batteries led to great hopes of a cheap system of distribution. It was said, "Put your generating station at a distance, on cheap ground, carry a current with high potential through light conductors to the district to be lighted. Pass the current through some thousand accumulators in series, placing these in batches of fifty (say) each, in cellars, to light up a small district." The original idea was to keep the service wires permanently attached to the two ends of each set of fifty cells.

Now, this plan is very beautiful if only it would work. But it will not work. The consumption being small from some of the cellars, and large from others, and the same charging current going through all of them the cells become overcharged in many cases, and this is injurious.

Another plan was proposed, which I described in my Cantor Lectures. This was to introduce an arrangement to indicate when the cells were fully charged. By having two complete sets of batteries in each cellar, the indicator caused a rocking switch to act, which switched the fully charged battery off from the charging mains on to the service mains, and at the same time switched the second set, which had, up to that time been supplying the service mains, on to the charging mains. Here I would point out that, independently of the fact that we have no reliable indicator to show when the cells are fully charged, this only moves the difficulty back one step. For it will often happen that both sets are fully charged, and yet we are obliged to send currents through one of them. This plan was tried at Colchester, but of course it had to be abandoned. If we had a true indicator to show when the cells are fully charged, the more sensible plan of using it seems to be to cause the indicator to disconnect the cells from the charging mains, and connect the charging mains metallically. There would, of course, be a great fall of potential in lamps immediately after switching off the supply current, but the charging of the cells might be done by day or after midnight, during which time lamps are not very much used. I think that even this small difficulty might be got over by causing the indicator when it acts to increase the number of cells which lead to the lamps.

I suppose the most reliable indicators which could be used are those depending upon the specific gravity of the solution or the weight of the negative (oxydized) plate. Unfortunately it is seldom found that a number of cells working in series become charged at the same time.

In fact, it is not very generally known that the most satisfactory plan for charging secondary batteries is to do so in quantity or parallel. When this is done, every cell is fully charged exactly at the same time, and all give off gas at the same moment. If there be any possibility of short-circuiting, however, fusible plugs or other cut-outs must be inserted.*

To have a thoroughly satisfactory installation, it is necessary that the cells may be left in their secluded retreats, without attention, for long periods. I think I can safely say that cells can be so left if fairly treated. But the question is whether any scheme of distribution hitherto considered does give them fair treatment. If attendants have to be continually going around to inspect cells, this expense must be carefully calculated so far as is possible, and taken into account.

Now let me say a few words as to the improvements in secondary batteries. First, I may say that there is now no doubt that they can be made, and are made, by several makers of so good a construction that they can be used for several years. I will not fix the number of years, because none of the most perfect ones have yet failed. Secondly,

* Even in this case we may have a partial short-circuit, which will drain the current and yet will not cut out the cell.

it seems to be conclusively proved that not only does no buckling take place, but there is no fluting or blistering if the plates are originally good, and if the air has not been allowed to reach them. Thirdly, we know that in overcharging them we do not injure them, but merely waste current. These are important facts, and are all we want for an installation where the state of the cells can be always under examination. For central station lighting we want something more. We want the cells to take current from the dynamos when they require it. For this we must have an indicator on the cells to work a switch, according to the state of charge of the current. Up to the present no satisfactory master-cell has been devised. Those which depend on the gas given off do not act equally promptly with currents of different strength. The most promising system is one in which the state of the cell is shown by the specific gravity of the liquid. Very little ingenuity is required to develop this into a satisfactory system. But we cannot depend upon one master-cell, since it is only when charging in parallel that all cells act alike. If we have several master-cells in each battery, all of which must act together to cut off the dynamo, I think we might depend upon their action. The function of the switch is—first, when the E. M. F. of the battery is too high, to cut out the dynamo circuit from the battery, to give a through connection to the dynamo current, and to switch in two additional cells to the lamp circuit; second, when the E. M. F. of the battery is too low, to break the charging current, to connect the battery to it, and to cut off two cells from the lamp circuit. These are all ordinary things which can easily be done.

But even without automatic action of this sort there are many large installations where it would be economical to use secondary batteries, even if attendants had to be continually examining the state of the cells. The engineer who is designing an installation, if he does his duty, calculates the cost of every method of working which can be feasible.

The cost is, of course, an important item, and were it not that this system introduces a great saving in copper conductors and machinery, it would often be too expensive to work. We may take the cost of batteries at about £3 per lamp of 60 watts. The saving in copper conductors is proportional to the number of batteries put in series. There is also a saving in dynamos and engines. If we take four hours as the average time of using the lamps, we charge them, say, for six hours in the day-time, and we use the dynamos as well as the batteries, during the greater part of the night. Thus we require batteries and dynamos for only about one-half of the number of lamps generally in use. This brings the cost of batteries down to £1 10s. per lamp, and the cost of dynamos and engines from about £1 per lamp (the usual cost for a direct service) to 10s. per lamp. This makes a total cost of £2 per lamp, as against £1 by a direct service. When we have made a further reduction for diminished size of conductors, and an increase for additional attendance, we are in a position to compare the two systems. But these figures vary so enormously that it is impossible to estimate them unless one has the details before him. We may say safely, however, that in large districts there is economy in secondary batteries, and in small districts in a direct service. But the advantage of not being dependent on the constant perfection of machinery is very great, and avoids the necessity for so complete a duplication of the parts. Of course the cost of working must also be made out, allowing for a loss of at least 20 per cent. in transforming through the secondary batteries.

The number of ways of using secondary batteries is great, but there are no engineering difficulties in the distribution, and I may, therefore, content myself with having drawn attention to the general advantages of using them.

Among the many special appliances used in this kind of work I am glad to be able to show you some useful things supplied by the Electrical Power and Storage Company.

Perhaps the most important of these is a switch for large currents, in which a number of concentric tubes have a longitudinal slot into which the arm of the switch is forced. The split tubes have a certain amount of spring, and literally cut into the arm of the switch, and so make good metallic contact. The one be-

fore you has been thoroughly tested with 1,500 ampères passing through it.

Another appliance is an automatic switch to reduce to number of cells in the lamp circuit when the dynamo is charging the cells, and *vice versa*.

A third is a cut-out to prevent damage to the charging dynamo by an accidental falling off of speed. It has this peculiarity, that it puts the battery in circuit again so soon as the dynamo resumes it functions.

In concluding this part of my subject I would draw your attention to the scheme of Lighting the Vienna Opera House. The dynamos are by Messrs. Crompton, of 72,000 watts each, and are driven by direct-acting Willans and Robinson engines. I am told that they give an electrical horse-power for 3.7 lbs. of coal. The secondary batteries are supplied by the Electrical Power and Storage Company. The three-wire system is adopted, 110 cells are ordinarily in use with each circuit, and 6 additional ones are available to keep the electric pressure constant.

Secondary Generators.

I now come to speak of secondary generators, and since the principles which regulate their action are rather novel, it may be well if I spend a little more time in describing their action than I would otherwise do in a lecture treating chiefly of the manner of laying main conductors.

Everyone knows the principle of the induction coil. It consists of a core of iron surrounded by a coil of insulated wire called the primary coil, and by another one of insulated wire called the secondary coil. The secondary usually contains a larger number of turns and finer wire than the primary. The current in the primary is alternately made and broken by a simple automatic means. This magnetizes and demagnetizes the iron core. This is equivalent to introducing and withdrawing a magnet into and out of the secondary coil, and sets up currents in the secondary coil.

The electromotive force created in each turn of the secondary coil is measured by the number of magnetizations per second, and by the strength of the magnetization. The latter is generally proportional to the number of turns in the primary, and to the current flowing through it. Thus the electromotive force in the secondary coil depends (1), on the number of turns in the primary; (2), on the number of turns in the secondary; (3), on the strength of current in the primary; and (4), on the number of makes and breaks in the primary current. Thus, by having a large number of turns in the secondary coil, and a small number in the primary, a very high electromotive force can be obtained from a small battery connected with the primary.

If, on the other hand, a high-tension interrupted current were sent through the fine-wire coil we could get a large current from the thick-wire coil.

Now, to feed a number of glow lamps in parallel we require a large current, but this requires a large conductor. Here it was proposed to use a high-tension alternate current (which acts just like an interrupted current) by a thin conductor from the works to the place of consumption, and there to transform it into a current of large quantity.

Then, again, another idea was thrown out. This was to carry the alternate current by a thin conductor around a large district, and at intervals to pass it through the first coil of induction coils, using the second coil to supply the lamps. Thus we should have a high-tension current disconnected from the service conductors, and furnishing them all with a low-tension current.

Induction coils used in this way have been called secondary generators or transformers. The perfection of manufacture of such apparatus consists in getting a maximum of induction and a minimum of heating. This has been admirably accomplished in the generators of Messrs. Goulard and Gibbs. Instead of wire, the coils are made of copper disks, or flat rings split at one point, and with ears projecting outward at the split. These discs alternately belong to the primary and secondary circuit, and successive discs of each circuit have the ears soldered together in such an order as to make up a spiral. The iron core is, of course, made of iron.

Although the even discs belong to the primary and the odd ones to the secondary, it does not follow that alternate discs should be coupled together. We may couple the 1st, 5th, 9th, &c., together,

and also the 3d, 7th, 11th, &c., so as to form two secondary circuits, which may be combined in parallel. The number of possible modifications of this sort is very great.

When the primary coil is magnetizing and demagnetizing the iron core, the latter sets up a counter electromotive force in the coil, and thus the current is largely diminished. But when there is no external resistance in the secondary coil, that coil being short circuited, then any magnetization and demagnetization of the core starts a current in the secondary coil, opposite in direction to that in the primary and almost equal to it. Thus the iron cannot get much magnetized, for it is surrounded by two opposing currents almost equal in amount. In this case, therefore, the primary has little or no counter electromotive force opposing it, and consequently it flows more freely. This explains a thing which often puzzles the beginner, viz., that with a constant electromotive force in the dynamo the current in the primary is stronger when the secondary circuit is closed than when it is open.

Very little energy is expended in magnetizing and demagnetizing iron wires. Thus there is really no loss of energy in the transformation, except that due to the heating of the conductors, of which the coils are constructed, which is equal to the square of the current multiplied by the resistance. The loss of energy, which could not be accounted for, has been shown by Professor Ferraris to be less than 1 per cent., and the practical efficiency of the generator amounts to as much as 95 per cent.

The theory of the secondary generators is very like that of the alternate current dynamo, if the reversals of magnetism of the armature were given by reversing the currents in the field magnets instead of by mechanical motion.

Coming now to distribution by secondary generators we find we must use the same principles as in direct distribution.

Parallel Distribution.—Let us take this case first. To do this economically we might lead two thin wires over the district and couple secondary generators to them. The condition of being able to have constant electric pressure in the lamps is that the electric pressure at the terminals of the primary should be constant. Here we meet the same difficulty as was experienced in direct supply. Consider three generators—1, 2, 3. If the lamps are all on in all three cases, then the pressure for No. 3 is less than for No. 2, and that again is less than for No. 1. Suppose you try to rectify this by using lamps of lower pressure at the far station. In this case suppose the lamps in No. 2 are extinguished, then the pressure in No. 3 will go up and tend to injure the lamps. If you try to correct this at the central station you will lower the pressure of No. 1 till perhaps it only burns red. This difficulty is exactly the same as in the direct service. The remedy is of the same kind. You must use the generators as distributing boxes (see my Cantor Lectures, 1885), with separate wires from the engine to each generator, each one being fed with a different pressure from the engine house. There is no objection to it except (1) that you must use a large number of conductors, and (2) you must introduce the full pressure of the high tension current into each house.

Finally, we come to distribution by generators in series. Here we have the best effect. A single wire goes round the circuit; if a double wire is used, to prevent affecting telephones, it is half the weight, and generators are alternately put on one wire and the other all round the district, and each pair of wires ends at a point far from the station. Suppose we use 10,000 volts, we may have 100 generators in series, each using 100 volts, or we may make any other arrangement. If it were done as I say, then following out the data of my Cantor Lectures, a wire of one square inch section will carry current enough for 100,000 lamps each consuming 60 watts.

In this arrangement we must send a constant current through the circuit. This is actually done by the introduction of resistances. It ought to be done either by an electric governor on the steam-engine, or by compound winding the alternate current machine, a matter about which there is no difficulty at all.

But how are we to attain to constant electric pressure in the lamps when we have got our constant current? This is a problem which has puzzled many people, and many have come to the conclusion that it is impossible to do it without

mechanism. This used to be done by automatically introducing the iron core farther or less far into the coils. It is now done without any relative movement of the parts. This is the last triumph which has been added to a series of laborious experiments which, year by year, have brought us nearer to a solution of our difficulties. I am not at liberty to explain the *modus operandi*, but I have seen it at work, and it is very satisfactory.

The theory of secondary generators has been so little studied, except by specialists, that I have thought it might be advantageous to many if I added to this paper the formulæ which represent the electric current and pressure as depending upon the resistances and mutual induction of the various parts. These data will be found in an Appendix to the present paper.

I do not think it would be consistent with the objects of this paper to describe the specific differences between different kinds of secondary generators, or to attempt to give reasons for choosing one of these forms rather than another. I would merely draw attention to the brilliant experiments on self-induction by Professor Hughes, described in his introductory address as president to the Society of Telegraph Engineers and of Electricians. Professor Hughes has discovered a new and hitherto unnoticed source of waste of energy in self induction, to remedy which it is essential to have the coils of the secondary generator made of discs.

I should also like, before leaving the subject, to dispel a growing error from the minds of some electricians. In speaking of different secondary generators, some persons are in the habit of speaking of one inventor's generator being used on a parallel system, another on a series system. This distinction is quite illusory. A generator made on any system is equally suitable for all kinds of distribution, and if an inventor states that his generator is only suited for one system of distribution he displays his ignorance, and shows that he has yet much to learn before he can say he understands the theory of secondary generators.

Last year, when speaking in my Cantor Lectures, I said that the Grosvenor Gallery installation would be followed with interest by engineers. I considered that it was a new test. Up to that time the method had been applied only to light districts where the number of lamps was constant. It was not proved that the method was suitable to the cases where lamps might at any moment be extinguished. Two things were necessary for this, (1) regulation of the current from the dynamo, and (2) automatic regulation of the electric pressure in the secondary circuit. Neither of these had then been accomplished in a manner which satisfied me, and I certainly considered it was a very bold step on the part of the Sir Coutts Lindsay to adopt a system which was then so imperfect.

I am satisfied now that self-regulation of the secondary circuit is sufficiently perfect for practical purposes, even when the generators are in series; and I have pointed out to Messrs. Gaulard and Gibbs a further development which, in my opinion, will make their system even more perfect. The one weak point in the Grosvenor Gallery installation is the regulation of the current from the dynamo. Out of the four or five different methods by means of which this can be done, the worst has been applied up to this time, viz., hand-regulation. The result is a frequent flicker in the lights. Still, when we consider that seven miles of route has been covered by the wires of this small association, and that on the whole great satisfaction is expressed by the users of the light, I must say that Sir Coutts Lindsay and his friends are to be congratulated on the great steps they have made toward success.

In conclusion, I wish briefly to allude to the present condition of electric lighting, and the prospects of economical distribution from central stations.

I have always maintained that there were three causes which retarded the progress of electric lighting:—(1), financial speculation; (2), the Electric Lighting Act of 1882; and (3), the unsuitability of the schemes of electrical distribution propounded by the contractors. I will say a few words on each in turn.

From the year 1881 to 1883 this country was the scene of a most senseless speculation, started by clever men of business, who took advantage of the interest in electric lighting caused by the

Paris and Crystal Palace Exhibitions, and supported by dupes whose ignorance of electrical matters was only equaled by their want of common sense as business men. These men combined to purchase for large sums the right to use the apparatus of some particular manufacturing firm in a special locality. They never asked any competent person whether this firm's apparatus was better or worse than that upon which there were no royalties to pay. Those who were not clever enough to get out of the affair before the bubble burst were the sufferers, and the consequence was a panic in connection with electric lighting which has hardly yet subsided.

With matured knowledge confidence is again being restored, because the public learn from competent and disinterested persons that economical electric lighting can be accomplished without the neces sity for paying the heavy royalties formerly demanded.

I trust that the warning of 1882-3 will not be lost on financiers, and that they will not be misled by untried but tempting schemes unsupported by capable men of science.

The next cause which has deterred electric lighting is the Act of 1882. This is an Act to give undertakers the right to break up streets in order to lay conductors, under certain conditions. It is these conditions which are so unjust. Some of our legislators, looking at the monopolies which exist in gas supply, are afraid that electric lighters will raise another monopoly. Consequently, they determined to hamper the electric lighting industry with conditions different to those imposed upon gas, and more stringent. They succeeded well, for they laid down such conditions that no sane man would invest in such a speculation. You would have thought it natural, I doubt not, that if the gas monopoly was truly so very irksome, the encouragement of a rival illuminant would have been the best cure for the evil, whereas our legislators acted as if they were parties interested in maintaining the gas monopoly, for they imposed such restrictions as rendered it impossible for electricity to be supplied to the public. Let me name one of their wise provisions: At the end of twenty-one years the local authorities can, if they please, buy from the company supplying electricity the whole of their plant at the price of old material, without paying a farthing for goodwill or future profits, or past expenses in experimental and unprofitable work.

If then a company, after twenty-one years, were just making headway, and paying a dividend of 5 per cent. on their capital, the corporation would buy them up for perhaps a third of that capital, and get 15 per cent. But the case is even worse if the company is not yet earning a fair dividend, for then the corporation may hang over the company like a usurer over his victim, and each seven years it has the right to purchase the plant or not, and on the same terms as before.

Now, I agree with those who contend that electricity should be allowed to compete with gas under the same disabilities, and with the same advantages. This is not doubling a monopoly; it is splitting it into two, and destroying the monopoly, by allowing competition. If our legislators are not trying to uphold the gas monopoly, they must take this view. In any case the public have shown that they will not submit to be deprived by legislation of this illuminant. The Board of Trade, I hear, have perceived their error, and are prepared to yield a little; but if they do not enable us to have electricity supplied to us, we, the public, must force their hand.

Still, electric lighting is not quite dependent on this Act. Local authorities have no penalties, and I would strongly urge them to take the matter up, for we have now arrived at a stage when it is safe and profitable to establish electric lighting on a large scale.

Again, you must remember that the disabilities of the Act apply only to those who lay their conductors underground and wish to break up the street. Sir Coutts Lindsay has taught us how to defy the Electric Lighting Act by passing the wires overhead. Those wires do not suffer like telegraph wires in snow storms, for the electric current melts the snow.

The third cause which deterred the progress of electric lighting, was the unsuitability of schemes of distribution which were proposed. I was impressed with this weak point at an early date.

Sir William Thomson was the first to touch on the matter when he announced his law of the economical size of conductors. But the engineer had no tables to guide him as to the safety of these sizes of conductors in the matter of heating. I attacked this problem first in order to clear the way for scientific methods of dealing with distribution. In a paper read before the Society of Telegraph Engineers and of Electricians, in 1883, I computed from the facts well known to physicists, the heating of different-sized conductors with different currents, whether the conductors were bare, insulated or buried. I had already, in a communication to the British Association in 1882, shown by experimental evidence, that the generally accepted laws required modification when we dealt with small wires.

The way being thus cleared, I attacked the problem of distribution generally, studying the various schemes which had been proposed or put in practice. My conclusions were published in the Cantor Lectures in 1885, and the most useful result was to announce a series of definite rules which must be attended to in order to provide an economical distribution. Since then some progress has been made, and the present paper will, I hope, bring the subject pretty well up to date.

The work which I undertook has been laborious, but it has been a very humble effort. I have brought forward hardly a single fact which could not have been foreseen by the competent engineer. But I think I have saved others from wasting their energy in repeating much of the work which is laborious; and I also trust that the outcome is a set of rules to guide those engineers whose purely scientific knowledge may be a little defective from falling into the gross errors which have been so apparent in nearly all attempts at lighting by electricity on a large scale which have been made in the past.

I now close the subject for a time, and if the labor I have bestowed upon it leads in any slight measure to establishing one department of electrical engineering on a sound scientific basis, I shall feel that in the work I have undertaken I have been of some little use to my generation.

Appendix.

The following formulæ give the currents and electromotive forces, on the assumption that the magnetism of the core varies as the sum of the currents in the two coils.

The E. M. F. of the dynamo is assumed as being:

$$E \sin, mt$$

Then the primary current $= I \sin (mt + \gamma)$

secondary current $= I' \sin (mt + \gamma')$

$$I^2 = E^2 \frac{C^2 + r'^2}{r^2 r'^2 + (r + r')^2 C}$$

$$I'^2 = E^2 \frac{C^2}{r^2 r'^2 + (r + r')^2 C^2}$$

Where C is a constant:

r = resistance of primary circuit;

r' = " secondary circuit.

Also the

potentials at primary terminals $= v$;

and " secondary terminals $= v'$;

where $v = V \sin. (mt + \varphi)$

$v' = V \sin. (mt + \varphi')$

$$V^2 = E^2 \frac{\rho^2 r'^2 + (\rho + r')^2 C^2}{r^2 r'^2 + (r + r')^2 C^2}$$

$$V'^2 = E^2 \frac{(r' + \rho')^2 C^2}{r^2 r'^2 + (r + r')^2 C^2}$$

ρ and ρ' being the resistances of the primary and secondary coils.

Discussion.

Professor Hughes, F. R. S., said in his latest researches he had found that the maximum induction in iron took place when the iron was in the round form. If it was flattened, so that the contiguous portions of the current became separated from each other, the current was very weak; it had not one-tenth of its previous capacity. In the case of copper wire flattened, the reduction in the self-induction was about 50 per cent. Taking iron wire and passing a current through it, if you wished to have a secondary current parallel to it, the self-induction prevented the current acting on the secondary coil; in fact, the force of the electric current was used up in doing internal work. By flattening it, it re-acted on another wire to its full force,

so that the energy which would have been used in self-induction, was transformed into the secondary current. He had not the slightest doubt that if this method were adopted, enormously more power could be obtained from the secondary coil. When the two wires were flattened, the portions contiguous to each other did not re-act on each other with the same strength, but re acted on any portion near; consequently, when there was another flattened sheet superposed, you had it in the nearest possible proximity. It was very remarkable that the same results at which he had arrived theoretically should have been worked out experimentally by Messrs. Gaulard and Gibbs, and they had arrived at the best possible conditions he could conceive for constructing a secondary coil. He had only one fault to find with it; the generator itself seemed perfect, but it required intermittent currents, and, therefore, it seemed to him there must be a loss in the line. He had been much interested in the paper, and hoped Professor Forbes would continue his investigations on this subject which he had made peculiarly his own.

M. Gaulard (who spoke in French) thanked Professor Forbes for his remarks upon the actual conditions and future prospects of the apparatus with which he was associated. He also thanked Professor Hughes for his expressions respecting the mode of construction adopted, and in answer to the objection as to the great loss caused by the use of alternate currents for leads of great length, he said he could rely upon the experiments made with their apparatus, and reassure Professor Hughes entirely on this subject. Their apparatus was constructed with two parallel circuits, forming spirals in the same direction. In order to obtain in the secondary circuit a variable electromotive force, they had contrived to unite in parallel and inverse directions the two circuits, and they had found that if in these conditions they sent through them an alternating current, the difference of potential at the ends of the spirals was directly proportioned to the resistance in the leads. If, on the other hand, they interposed in one of the connections a resistance, they found that the difference of potential at the two ends of the secondary circuit was, to a certain extent, directly proportioned to that resistance. From these observations it followed that if the leads consist of two parallel wires, and currents in opposite directions are sent through, not only no phenomenon of induction on the outer external circuit can appear, but no self-induction on these two leads can exist any more. As a practical demonstration of these results he quoted the experiments made in 1884, near Turin, on a line of 80 kilometers, which the kindness of the Telegraph Administrators of the Government had allowed them to establish on their telegraph poles. By reason of the limited space, the two wires (out and home) were placed at a distance of 15 centimeters from each other, and at the same distance from the telegraph wires. When properly insulated, the telegraph engineers ascertained that their apparatus had not been affected by any induction, and the jury, in determining the loss by the resistance in the leads, likewise ascertained that this loss was equal to the produce of the square of the intensity of the current in the lead by its own resistance.

Mr. Kapp said he did not know much about the distribution of electricity, but he should like to add one more to the list of improvements which had been placed at the service of the electrical engineer, and that was the reduction which had been made in the speed of the dynamo. If electricity were to be distributed for domestic use, you must be quite sure that there should be no breakdown; that was an imperative necessity, and the best way to ensure that was not to drive the machine at too high a rate of speed. Within the last few years the tendency had been to reduce the speed of dynamos by designing them in a more scientific way, making use of stronger fields, and of altogether better mechanical construction. Machines were now running at half the speed of those constructed a few years ago, and in this way the chances of failure were enormously reduced.

Mr. B. Drake remarked that Professor Forbes had drawn attention to the different ways in which electricity might be distributed for lighting purposes, but had not fully compared the relative advantages and disadvantages of the different systems. On behalf of secondary batteries, he would claim advantage in

the practical impossibility of totally extinguishing a district through the failure of a single wire. No doubt there were many points which might be claimed on behalf of secondary generators, such as the first cost being less, and there being stronger metals in use, which would be likely to last longer than lead plates, but at the same time the contingency of a station being extinguished all at once was an important consideration, and the fact of the engine having to be run to its full power whenever all the lights were required would more than balance the small extra cost of the accumulators in the first instance. The question had been raised as to the different details of apparatus necessary in connection with secondary batteries; they had been experimenting with every kind of apparatus for the last eighteen months, with a view to ascertain how far it was really worth while to complicate the system by putting in automatic contrivances, and after designing all sorts of apparatus, they had come to the conclusion that the whole thing ought to be kept as simple as possible. For instance, Professor Forbes had referred to an apparatus by which, when the dynamo started charging, the number of cells in circuit might be reduced. That was a very easy mechanical problem to solve, and such an apparatus had been made; it was designed specially for train lighting, where an accumulator was to be placed in each carriage and charged in series, so that a train might be split up without difficulty, and accumulators charged in this way would really be a model of what was required on a larger scale for district lighting. Then they had to face the question of cutting off an extra cell as soon as the dynamo was put into the circuit; but it was found that the question of the accumulators being either fully charged or practically empty made so much difference to the electromotive force between the terminals, that to cut off any fixed number of cells was practically barely worth the trouble. When a cell was practically empty, you required only 2.2 volts to charge it with a certain current, whereas to get the same current through it when the cell was full required over 2.5; the cutting off of a definite number of cells was therefore practically not worth the cost of the apparatus. It was, however, found advisable to introduce some kind of automatic switch in any installation where the attendant ever had to leave the engine. There was again the question of the regularity of the light. If the engine power varied at all where secondary generators were used, that variation was transmitted throughout the whole district; if a bearing ran hot, all the lights felt it; and in addition to that, there was the variation which Professor Forbes now said had been nearly overcome, which was due to varied consumption at different points of the circuit. With secondary batteries none of these evils occurred, and if some apparatus could be made reliable for cutting them in and out when fully charged, it seemed to him the solution of the problem would be complete. He agreed with Professor Forbes that the specific gravity was the right principle to adopt in cutting out the accumulators, and that the master cell system would be much improved by having two master cells which would have to be completed before the automatic cut-out would work. The difficulty with the specific gravity apparatus was this: The carrier which carried the whole apparatus had to float as well as the hydrometer, and in order to do that, the cell containing it had to be enlarged. In that way the bulk of the acid was enlarged, and consequently, the range in specific gravity became so extremely small, that you could practically do nothing with the small variation of the hydrometer. On the other hand, with the extremely small space which was necessary to get any appreciable variation, you had to employ such a small apparatus, that you could hardly rely on its working properly. The only way to get any results was by a system of relays, and that was difficult near accumulators, because the contacts got corroded by the acid. No doubt the advocates of the other system would be able to point out objections to secondary batteries, and he should be much interested in hearing them.

Mr. Shoolbred said it had been stated that the difficulty of knowing the state in which secondary batteries were, when they were fully charged, and when they were getting exhausted, had been got over by the use of hydrometers. He

should like to know if this had proved really successful.

Mr. Drake said he had just been explaining that the great difficulty was the confined space. He did not know of any case where they had been used practically for actuating switches automatically.

Mr. Mordey thought the carbon resistance gauge shown was very similar to that which had been made for years by the Brush Corporation, consisting of a series of small carbon plates in a case, with a screw or lever arrangement to enable the resistance to be varied by alteration in the pressure. The principle had been used by Mr. Brush in his automatic regulator. The original principle he believed was due to M. Clerat, who communicated it to Professor Hughes in 1867. With regard to lamps of low resistance, he might say that on some circuits at Eastbourne and also at Brighton, the plan had been in operation, not with so low a resistance as Mr. Bernstein used, but so low as to allow of three lamps in a group being used, instead of eight or nine; each lamp taking a current of 3.3 ampères, the normal working current being 10 ampères. The manipulation of a group of lamps was very much simplified when the number was reduced; and if it could be reduced to one, and a constant current could be maintained through the circuit, the perfection of simplification would be attained; but even where three had been used in a group, with about 15 volts at the terminals, the manipulation of each group was not a serious matter. Where people employed a large number of lights, they might object to turn out eight or ten, but the same objection did not apply to a group of three. He should like to ask if there was any advantage in using secondary generators in the manner shown in the diagram in parallel; it seemed to him that all the effect thus obtained could be obtained much better by the ordinary direct supply. The cost of leads and the whole of the problems connected with the question would be of much the same in each case. Another point in connection with secondary batteries was of great scientific interest, and that was as to the actual loss of energy in the iron of the core due to the rapid magnetization and demagnetization. There had been a great deal of discussion of late years as to whether any energy was really lost in this way, and it was a very difficult subject to work at, because it was almost impossible to eliminate the effect due to eddy currents, and that due to the turning over of the molecules, as Professor Hughes would call it. In an ordinary dynamo machine, where the reversal of polarity was not so rapid, only 400 or 500 revolutions a minute, and the molecules only required to be turned over 800 or 1,000 times a minute, the difficulty was not felt, but in secondary generator coils, where the reversal of magnetism took place thousands of times in a minute, it would be very different, and he should like to know if the actual loss had been ascertained.

M. Gaulard, in answer to the observations of Mr. Drake respecting the great loss which might result from the retardation in the molecular vibrations, produced by a very great number of alternations—an opinion based upon certain facts observed in the use of a current having 1,000 alternations per minute—he would point out again that, in the experiments made by the international jury of Turin upon the secondary generators by the most exact method, the calorimetric method, the current used had 16,000 alternations per minute; the yield had been proved to be 95 per cent. This is the greatest number of alternations obtained till now, by an alternate current machine of the largest type known, and perfectly sufficient, he thought, for producing the highest electromotive force which may be wanted from a practical point of view.

The Chairman drew attention to the several points which had been raised by Professor Forbes, and which had been brought out in the discussion, such as the relation of the size of conductor to the mode of distribution, and especially the part played by secondary batteries, and again, the important applications of secondary generators so ably explained by M. Gaulard. Now that electric lighting was not going forward with such hot haste as it was two or three years ago, those who were connected with it had more time to think about the best and most efficient methods of doing the work, and the lull would be found to be a time of great profit to electric lighting. We may be thankful to Professor Forbes for making the question of the size and ar-

rangement of conductors so much his own, and for giving us the benefit of his researches in this direction. We must also thank him for so ably bringing before us in the Cantor Lectures, and in his paper this evening, the results of a great deal of thought and experiment on the different systems of lighting. Thanks to his and other researches, we may say that electric lighting is on a much more stable basis than it was three years ago. When it was stated that you could depend on getting out of storage batteries 70 or 80 per cent. of the energy employed, it was evident that a great step had been made during the last three years. Coming to the question of secondary generators, a very successful experiment had been made—indeed, it was almost more than an experiment—by Sir Coutts Lindsay. He might also refer to the experiment made some time ago by Messrs. Gaulard and Gibbs, in which they lighted up part of the Metropolitan Railway—from the Edgware Road station to Aldgate in one direction, and Notting Hill Gate in the other—from one central station. The apparatus exhibited this evening showed that even then they had made very great progress, and that they had gone far ahead of the position to which they had then attained.

Professor Forbes, in reply, said some of the points raised had been already answered. M. Gaulard had replied to Professor Hughes by telling him of the effect of the double line; and he would observe that in doubling the line it was not necessary to double the quantity of metal, because, as shown in the sketch of the series arrangement, when you doubled the line, you tapped both wires, and therefore made the wires half the section they would otherwise have been. He ought to have congratulated Mr. Kapp on the improvements he had effected, but he should congratulate him on increasing his magnetic induction and the capacity of his machine, more than on diminishing its speed. It was perfectly true there might be less chance of failure in a machine when running at half speed than at the speed it used to run, but at what a tremendous cost that safety was obtained. The machine ought to do double the amount of work it did at that reduced speed. When there was a central station to light, the dynamo must be run at a reduced speed, but it must be made up for in another way by increasing the size. When there were large districts to light, it would be economical to have large machines going at comparatively slow speeds. When Mr. Drake came to look at the paper, he thought he would find that he had given full credit to the advantage he had mentioned of a district never being put in darkness through one wire breaking. He was sorry to hear that the sum total of eighteen months work was, that they could not leave the batteries alone to automatic appliances to work themselves, and he trusted that Mr. Drake would reconsider that question. He hoped to see secondary batteries largely used in central station-lighting, but if it involved the necessity of attendants going round to look after them and switch them in and out, it would be a serious drawback to their introduction. He ought to have mentioned that it was Mr. Drake who originally suggested to him the use of two master cells. He could not give Mr. Shoolbred any more information with regard to the use of hydrometers than Mr. Drake had furnished. In reply to Mr. Mordey, of course he did not mean to say that the use of carbon plates as an adjustable resistance was new, but he drew attention to this instrument of Mr. Varley's because he believed it was new, and it possessed advantages he had not seen in any previous arrangement. It was perfectly adjustable by the screw, and did not require knocking on the table to shake the pieces apart, as he had found with Mr. Brush's apparatus. With regard to the advantage of using secondary generators in parallel, he would point out that if the station were at a great distance, very thin conductors might be used to the generators. You might use a primary circuit of any series, and take as the secondary coil a number of discs in parallel, and so use a high tension current, thousands of volts in the primary, and yet have only 100, or whatever was required, in the house, and have all the economy of thin conductors. With regard to the loss of energy in magnetizing and demagnetizing, he agreed with M. Gaulard that it was an extremely minute quantity which could not be detected; the loss when a core of iron wire was used was very small indeed.

THE WATER SUPPLY OF SOME GREAT CITIES.

From "The Builder."

THE pure inland seas and mighty rivers of North America afford to the inhabitants of that quarter of the world an unstinted supply of water, for all purposes of navigation, cultivation, mechanical power, and domestic use. The Mississippi River alone drains an area of more than ten times the extent of the United Kingdom. The surface of the water of Lake Superior, at a level of 628 ft. above the sea, covers an area larger than that of the whole of Scotland. The length of the inland navigation, from the Straits of Belle Isle to Fond-du-Lac, at the head of Lake Superior, is 2,384 statute miles, and from the same point of starting to Chicago, on Lake Michigan, almost exactly the same distance; while the ocean navigation from Belle Isle to Liverpool measures only 2,234 statute miles. The Ohio River, from which the great city of Cincinnati derives its water supply, has a mean annual flow of 150,000 cubic ft. per second, and is 4,000 ft. wide when it falls into the Mississippi, nearly 1,100 miles above the mouth of the latter river. Lake Michigan, on the borders of which has risen the most rapidly-developed of all the great cities of the New World, namely, Chicago, has an area of 23,000 square miles. It is 320 miles long, 100 miles broad, 628 ft. above the level of the sea, and is said to be 100 ft. deep. The Croton River, at a distance of 33 miles above New York, is raised by a dam to a height of 166 ft. above mean-tide level at that city, and its waters, led thence in an aqueduct, flow at a level which provides for the supply of 90 per cent. of the area of that city by gravitation. Thus, whether we regard abundance and purity of water, or natural facilities for its distribution by gravitation, every imaginable form of convenience to the dweller in cities for the supply of his need of this great necessary of life is offered by nature in the United States. Nor is there any part of the surface of the globe in which the skill and perseverance of man have been more efficient in making the best of the gifts of nature.

It is thus of no small interest to the residents of older and more densely-populated countries, especially in those localities where the rapid increase of population has attained such a density that the citizens could not be supplied with enough water from the skies above them, even if every drop that fell over the districts in question could be caught and stored for use, to ask what the genius of the American engineer has done to supply the need of the urban population of the chief great cities of that continent from the inexhaustible stores of its lakes, rivers, and running and falling waters.

In the United States exist (or existed at the date of the last census) but ten cities of each of which the population exceeds 200,000 souls. In the United Kingdom, excluding the metropolis, there were also, at the date of the last census, only ten cities of each of which the population exceeded 200,000 souls.

On the Continent of Europe twenty-four capitals and great seaport towns exceed that population; but neither are the data so well ascertained, nor the conditions so distinctly characteristic, as is the case with the cities of the United States. The 3½ million residents of our ten great centers of population, and chiefly those of the metropolis, who form a yet larger body of water consumers, may well look with interest to the outcome of the experience of 5 millions of townsfolk (in 1880, 4,855,000), of kindred race, placed amid the unfailing waters of North America.

Of these great cities, three, viz., New York, Brooklyn, and San Francisco, have laid out in the aggregate about the same sum that has been expended on the London waterworks, in order to obtain the advantage of a supply by gravitation, for an aggregate population little more than half that of London. Boston also depends on gravitation, drawing its supplies from the Sudbury river, and the Lakes Cochituate and Mystic. Philadelphia pumps to reservoirs, from the Schuylkill and Delaware rivers. Baltimore depends partly on gravitation and partly on pumping, taking its supplies from Jones's Falls and Gunpowder Rivers. St. Louis

and New Orleans pump to reservoirs from the Mississippi, as does Cincinnati from the Ohio. And Chicago, as original in its mode of procuring water as in so many other features of its masterly engineering, draws its supply from the pure water of Lake Michigan, through a tunnel of two miles in length under the bed of the lake, fed through a down-pipe at the end in a depth of 32 ft. of water. Alone among these great Western cities, Chicago (owing to its low level) adopts the old-fashioned English mode of pumping to a stand-pipe. Of all the ten cities, the cost at Chicago is the lowest, whether as regards outlay of capital in proportion to the number of inhabitants, or working cost per million of gallons. On the other hand, so freely is the water dispensed in Chicago, that the daily delivery averages 109 gallons per inhabitant. It is of interest to take note of the growth of the city which, so far as present information goes, has at once the cheapest and the most copious water-supply in the world, although, owing to the liberality with which it is dispensed, the annual cost per inhabitant is higher than that in either New York or Philadelphia.

The population of Chicago, which, in 1830 was seventy persons, became in

1840	4,583
1850	29,963
1860	112,170
1870	295,977
1880	503,185

Language fails to add to the force of these figures. From 1870 to 1880 the increase has been nearly sixty souls per day.

The waterworks of Chicago, as they existed at the date of Sir Charles A. Hartley's visit in 1873, were described by that engineer in a paper communicated to the Institution of Civil Engineers in the following year. It was found, Sir Charles says, by careful borings, that a bed of compact blue clay, at least 100 ft. thick, underlay the thin crust of silt and sand which formed the bottom of the lake. On this bottom, at the distance, as before said, of two miles from the shore, was formed an artificial island to serve as the locality for a shaft at the lakeward end of the tunnel. For this purpose a crib or timber frame, of a pentagonal plan, 90 ft. in diameter, 40 ft. high, and with walls 25 ft. thick, was constructed on shore, towed to the selected spot, and filled, in fifteen prepared compartments, with 6,000 cubic yards of stone to sink it to the bottom of the lake. The top of this structure, when settled into place, stood 5 ft. above the water, and in the center of the mass was a sort of open well, of about 30 ft. in diameter, Within this framework, which contained 50,000 cubic ft. of whole 12-in. timbers, a column of seven cast-iron pipes, of 9 ft. in diameter, and of a total length of 63 ft., was sunk through the clay to 31 ft. below the bottom of the lake. The clay was excavated within as the pipe sank, and the tunnel was started from below to meet that previously commenced from the shore. This gallery is nearly circular in section, being 5 ft. 2 in. in depth, and 5 ft. in width, and consists of two rings of brick in cement, 8 in. thick. It was started from each end, the lake end being commenced eighteen months later than the work from the shore. The land shaft is sunk to 70 ft. below the level of the lake, and 77 ft. below that of the ground, so that the tunnel has a landward fall of 7 ft. in the whole distance. The two excavations met at about one quarter of the distance from the crib to the shore.

Four steam pumping-engines were provided for the service of the city, but at the commencement of 1873 a new double-beam engine was started as a relief. This, which is said to be the largest pumping-engine in the United States, has two 70-in. steam cylinders with 10-ft. stroke, and works two pumps of 57 in. diameter, delivering 36 millions of gallons of water in twenty-four hours. If worked together with the other engines there is a combined capacity of 75,000,000 gallons per twenty-four hours. A standpipe, 140 ft. above the level of the lake, is protected by a stone tower 170 ft. high. The pumps are considered to force the water to a height of 132 ft., but in the daytime the delivery is said not to rise higher than the second story of the houses. The water is supplied through thirty-eight miles of mains, the largest of which have a diameter of thirty-six inches.

The power of delivering a daily supply of water equal to half of that now demanded by the wants of 4,000,000 of Londoners was not, however, enough to

slake the thirst of Chicago. A second intake-shaft and tunnel were in progress at the time of Sir Charles Hartley's visit in 1873, and a land tunnel, 7 ft. in diameter, was pierced for four miles westward of the lake, in order to supply a second set of pumping works to accommodate the extension of the city. By the year 1880, as we learn from Mr. J. J. R. Croes, the author of "Statistical Tables of the Water Works of the United States," the sum of £1,868,000 had been expended on the water-works of Chicago, the annual revenue from water rentals amounted to £206,000, and a mean quantity of 109½ gallons per head of the population was daily supplied.

With this enormous volume of water, and with the simplicity of arrangement which the unlimited supply and the low level of delivery render possible, it is not matter of wonder that the working cost of water delivery in Chicago is by far the lowest in the world. In the nine years ending in 1872 the cost of delivering a million gallons of water varied from 52s. to 32s. In 1882 it had fallen to 22s. But the revenue of the works amounted, in the last-named year, to £10.26 per million gallons, and the cost per inhabitant, owing to the copious nature of the supply, was 26 per cent. higher than that incurred in the same year by the inhabitants of London.

While Chicago is thus the cheapest of the great cities of the West, in the procurement, if not in the sale, of water, the lowest cost per inhabitant occurs in New York. We must, indeed, make exception in favor of San Francisco; but the figures stated with regard to the latter city are in some respects so anomalous that we await the result of inquiries made in the United States on the subject before quoting them to our readers. Of nine of the ten cities, certainly, New York is at the same time the cheapest, and the only one that supplies water at a less rate per inhabitant than the average price in London. Yet the capital laid out on the New York water-works is £5.84 per inhabitant, while that in Chicago is only £3.73 per inhabitant, and the working cost per million gallons is nearly twice as much in New York as in Chicago, while the revenue is only about 3 per cent. more.

The water supply of New York is provided by the construction of a dam across the valley drained by the Croton River, about six miles from its mouth, which raises the water to a height of 40 ft. above the original level at that point; or to 166 ft. above the mean-tide level at New York. From this dam to the Harlem River, which is crossed by an aqueduct containing eight arches each of 80 ft. span, and seven arches each of 50 ft. span, runs an uninterrupted conduit of stone and brick masonry, set in hydraulic cement, of thirty-three miles in length, including a tunnel through rock. The Harlem Aqueduct was built to carry two cast-iron pipes, each 4 ft. in diameter, at the level of 108 ft. above mean tide; but a 7½ ft. diameter pipe of boiler plate was laid down in their place. The masonry conduit is continued for two miles from the Harlem Bridge. Then the Manhattan Valley is crossed by syphon pipes, and two miles more of conduit and aqueduct brings the water to the received reservoir at New York. This reservoir, formed in two divisions, has an area of 31 acres, and a capacity of 150 millions of imperial gallons. It is connected with a distributing reservoir of an area of 4 acres, a depth of 36 ft., and a capacity of 20 millions of imperial gallons; an additional receiving reservoir of an area of 106 acres, and a capacity of 1,000 million gallons; and a new storage reservoir in the Croton Valley, of three times the last-named capacity, raises the combined capacity of the whole of above indicated reservoirs to 4,570,000,000 gallons. And yet another reservoir in the Croton Valley was in course of preparation, at the time referred to, with a capacity of 3,700,000,000 gallons; the object being, in case of the occurrence of long droughts, to provide for 82 days' consumption of the city, at the rate of 100 gallons per head, irrespective of the minimum daily flow of the Croton River, of 27,000,000 gallons.

For the supply of the higher section of the city, north of the Manhattan Valley, a high service reservoir is constructed, into which water is pumped by steam from the aqueduct near Harlem Bridge. And the very highest points are fed from a tank supported on a tower, near the last-named reservoir, at a height of 300 ft. above the sea. In 1882 the ordinary daily consumption of the city was 95,000,000 American, or ordinary wine, gal-

lons of water; and the high service supply amounted to a further quantity of 11,605,630 American gallons. The cost of the works has attained the large figure of £7,000,000, or £5.84 per inhabitant. The annual revenue was £343,000, or 5.7s. per head, and the working cost was £70,000, or only 1.14s. per head. The daily supply per inhabitant was 74 imperial gallons.

An instructive comparison of the two opposite methods of supply by gravitation and by direct pumping is afforded by the statistics of the water supply of Chicago and of New York. In the former, where £3.73 per inhabitant has been laid out in the works we have enumerated, the cost of pumping to the height of 132 ft., and of the entire distribution, amounted (for an annual volume of 20,124 millions of gallons) to the incredibly low figure of £1.11 per million. In the later, where one-tenth only of the supply has to be pumped for about the same lift as at Chicago, the working cost for the delivery of 32,425 millions of gallons in the year 1882 was £2.18 per million. The sum of £5.84 per inhabitant had, as before said, been laid out on the works. If we allow the whole price of pumping and distribution at Chicago as an extra charge on the proportion of the New York supply that has to be pumped, we have a cost of £2.07 per million gallons for the working expenses of the gravitation supply, including the maintenance of its large reservoirs, forty miles of aqueduct, and its other works, against a cost of £1.11 per million for direct pumping; and this, too, with coal costing 28s. per ton.

It is thus evident that it is altogether idle to attempt to prescribe the cheapest method in which the water supply of any given locality can be effected without due consideration of all the features of the case. It is, of course, clear at the first glance that, other things being equal, it is cheaper to supply water by gravitation than by pumping, independent of the extra strength of pipes and fittings that is required in the latter case. But the cost of the storage works has at the same time to be taken into account; and that both as involving interest on money and cost of maintenance. The interest on the New York gravitation works, if taken per head of the population supplied, is, as we have shown, to that on the Chicago direct pumping works, as 5.84 to 3.73. But this is not all. The maintenance of these noble works, together with all the other working expenses of supply, raises the working cost at New York to nearly double that at Chicago.

Perhaps the nearest approach to a comparison of the same nature between towns of a certain magnitude in England is afforded by the cases of Worcester and of Plymouth. In the former city the water of the Severn, running through the place, is pumped to a reservoir, at a cost of £7.06 per million gallons. In the latter, from works first constructed in the reign of Queen Elizabeth, the waters penned up in a mountain valley are conducted through a leet or open channel, of some twelve miles in length, into reservoirs for distribution, close to Plymouth. The average cost is returned at figures that do not work out to more than £1.41 per million gallons. Here the cost of maintenance is very low, and comparatively little has been done to aid the resources provided by nature herself. With these two localities as instances of the cheapest water supplies in England may be compared the supply of Kingston-upon-Hull, where the water is drawn from two artesian wells, and pumped into service-reservoirs of a capacity of about two days' supply of the town. Here the working cost comes to £7.34 per million gallons, which is close upon that at Worcester. For the Kent company, among those of the metropolis, which also relies on pumping from springs, the cost comes to £8.95 per million gallons. It is readily intelligible why cost should be higher in the last case than in the two former; but the comparison tends to show that the cost of our urban supplies is, for the most part, very closely approaching the minimum possible under the physical features of the case. The cost to the consumers, in the exceptionally favorable case of Plymouth, according to the figures given in the Return of Urban Water-supply (265, 1879), is at the rate of £7.01 per million gallons, which is a lower figure than that in either of the great cities of the United States. Water is sold by meter at Plymouth for 2d. per 1,000 gallons, which is equivalent to £8.33 per million. The rates outside the borough are 50 per cent. higher than

within, averaging 3.33 per cent. on the rental. But the question of the amount of rate legally chargeable is always liable to so much complication, that any statement of it conveys little information, if compared to that mode of application which we have followed, viz., rate of cost per million gallons, and rate of charge per inhabitant; the two figures being connected with each other by the rate of daily supply. Correcting the population given in the Return of Urban Water-supply by the increase from 1871 to 1879, the cost of water per inhabitant at Plymouth is 2.4s. per annum, and the daily supply is 46 gallons per head.

ENGINEERING PROGRESS.

ABSTRACT OF THE INAUGURAL ADDRESS OF PRESIDENT PERRY FAIRFAX NURSEY OF THE SOCIETY OF ENGINEERS.

From "Iron."

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I THEREFORE pass on to other themes, and propose, in the next place, to bring under your notice, some of the greatest achievements of the modern engineer in directing the great sources of power in nature in one special department of engineering, and the insignificant results accruing therefrom as compared with those arising from the development and exertion of analogous forces by nature herself. I shall then ask you to bear with me whilst I allude to the advanced position of engineering science, and then point out how prone we sometimes are to be so dazzled by the brilliancy of the light of that science as to be unable to see, or, seeing, refuse to believe, that some of those marvelous workers of bygone ages ever possessed a scintilla of scientific knowledge as we understand it, because the evidence thereof has not come down to us in the shape of text-books or treatises, and because we cannot fathom, or do not understand, all the deeper principles underlying some of their most majestic creations. I shall then take you back with me towards the childhood of the world to see if we cannot discover in the long past, the well-defined shadows of some of those things which we deem to be of essentially modern creation. I think we shall find that the principles underlying some of the most remarkable inventions and discoveries ascribed to our own times were by no means unknown to the ancients, and that in some instances the inventions themselves have been distinctly anticipated.

In considering the results accomplished by the modern engineer in directing the forces of nature, my experiences with explosive compounds lead me to look at the question more particularly from this point of view. In our explosives we have one form of condensed or concentrated power, resulting from an ingenious and intimate admixture of all the elements which it is necessary should be united in combustion, including oxygen, so that in action they are independent of the atmosphere and will explode under water. Man thus, by simple means, collects, compresses and stores up some of the forces of nature in a portable and handy form, and at the proper moment releases them and utilizes their power by directing it against those formidable obstructions which it is sometimes found necessary to remove in the interests of material progress and civilization. By the application of heat in one form or another, this stored-up power in a high state of tension is instantaneously set free, and acts with a greater or less degree of intensity according to the nature and composition of the explosive. The most common forms of explosives are gunpowder, guncotton and dynamite, combustion in the first being comparatively slow, and in the two last inconceivably rapid. It is this rapid development of intense power in dynamite and its congeners that renders it so useful to the engineer in removing large masses of rock in a short time, and at a comparatively small cost. Although I have done a certain amount of blasting in ironstone mines and open workings, I cannot lay claim to having fired any very big

charges. My heaviest blast was made with 115 lbs. of lithofracteur, a species of dynamite, possessing about the same strength, but exerting a greater rending power, and being a nitro-glycerine preparation. This was on the Jersey Harbor works, where Sir John Coode desired to remove, among other obstructions, a wall of rock which was standing out from the main rock, but running in a line with its face, there being a space of a few feet between the two. This wall was about 20 ft. high, 19 ft. long, and 12 ft. thick, the foot being exposed for a short time only at low water, and the rock being nearly covered at high water, ordinary tides, thus affording the advantage of the resistance of a good head of water for tamping. At low tide I planted my 115-lb. charge in the angle formed by the wall and the main rock, with the capped fuse inserted, which I led up to the top of the rock. At high water, which happened to be at midnight, I rowed out, landed, lighted my fuse, rowed away, and in a short time heard the low rumble of the subaqueous explosion, and the tumbling of the water. The next low tide revealed the wall of rock reduced to fragments and lying on the bottom, the explosion having also acted in a downward direction. It was computed by the engineer of the works and myself that at least 400 tons of rock had been dislodged by the blast. This gives about 3½ tons per lb. of explosive used, which may be taken as a fair average of what it should do.

In the autumn of 1879 I witnessed two heavy blasts with gunpowder at some granite quarries on the western shores of Loch Fyne, near Inverary. The first of these blasts was effected with 3 tons of gunpowder at the Crarae quarry, which is about eight miles from Inverary, and the second with 5 tons, at the Furnace quarry, which is some two miles nearer that town; both quarries belong to Mr. Sim. The quarries present extensive faces, and it is mainly the faces which are brought down, the powder being disposed in galleries to the rear of the face, and as near as possible to the dividing joints of the rock. The mines were fired by electricity, the 3 tons of powder in the Crarae quarry bringing down an estimated aggregate of about 60,000 tons of granite, and the 5 tons at Furnace about 100,000. This gives in each case 10 tons of rock per pound of powder, but it is to be observed that the conditions of work were comparatively easy, the face only requiring a forward heave to detach and throw it down on to the floor of the quarry below.

There are two cases of heavy blasting with gunpowder on record, which I may here refer to in passing. The first of these was the removal of the Rounddown Cliff at Dover in 1843, in which operation 18,500 lbs., or 9¼ tons, of gunpowder were disposed in three separate charges, which were fired simultaneously by a voltaic battery. The second case was at Holyhead, when the harbor was being made. One of the heaviest blasts there was 12,000 lbs., or 6 tons, of gunpowder, divided up into several charges and ignited simultaneously by means of a platinum wire heated by a Grove battery. The total quantity of rock stated to have been removed by this blast was 40,000 tons, or 3.33 tons per pound of explosive.

In the early part of last year a considerable blast was effected with dynamite in a stone quarry at San Francisco. Four galleries were driven each 50 ft. into the rock, and were returned at the end at right angles, forming a letter L. The explosive, of which 5½ tons were employed, was placed in the return galleries, the charges being tamped with debris. The four explosions were arranged to occur successively, the first to loosen the rock and make the work of the next easier, and so on with the second and third. It was estimated that the 11,000 lbs. of explosive had displaced 35,000 tons of rock, being a little over 3 tons per pound, and thus practically agreeing with my own experience.

The heaviest known blast, however, I believe to be that which was successfully accomplished last autumn at the entrance to East River, New York, known as Hell Gate, when 150 lbs. of nitro-glycerine compounds were exploded simultaneously in removing Flood Rock. Nine years previously, namely, in September, 1876, the most extensive blasting operation up to that date was successfully accomplished in the demolition of Hallett's Reef at the same place. The area then operated upon was three acres, and the weight of nitro-glycerine preparations (chiefly dynamite) used was about 25

tons, the quantity of rock demolished being estimated at over 63,000 cubic yards. Assuming the rock to weigh 2 tons to the cubic yard (that was the weight of the rock in Jersey), we have 126,000 tons of rock removed by 50,000 lbs. of explosive, or rather less than three tons per pound. After the removal of Hallett's Reef, operations were carried on at Flood Rock on the opposite side with a view to its removal, and by this means to render safe the navigation of the channel. On October 11, 1885, this object was successfully accomplished by the aid of 150 tons of explosives, which is six times as much as was used on Hallet's Reef, and which constitutes the biggest blasting operation on record. In this case, nine acres of rock were honeycombed, and charged with 75,000 lbs. of No. 1 dynamite, and 240,000 lbs. of rackarock, which is one of the potash class of explosives. The nine acres of rock had been pierced from below with four miles of tunneling in galleries, the floors of which were from 50 to 64 ft. below mean low tide, with walls of from 10 to 24 ft. thickness between them, and supported by 467 columns of rock, each 15 ft. square. In the columns and rock roof of these galleries nearly 14,000 holes, of an average depth of 9 ft., had been drilled, and each was charged with a 6-lb. cartridge of rackarock, and a 3 lb. cartridge of dynamite. These were all connected by a battery, so as to be exploded by a single electric spark. The shock of the explosion lasted about forty seconds, the visible results being the raising of an enormous volume of water to a height of 200 ft. into air. Upon subsiding, it developed a mass of broken rock, from which fire issued for a short time, but in two minutes more everything was quiet. No damage was occasioned to property, although a tremor caused by the explosion was felt at some distance. An examination of the rock showed that the explosion had been completely successful. General Newton, the chief engineer, states that it will probably cost half a million of dollars and take two years to remove the masses of broken rock. When the work is completed the channel will be 1,200 ft. wide, instead of 600, as at present, and 26 ft. deep, enabling ocean steamers to enter at all tides.

Such are some of the results produced by modern engineers with the aid of the most powerful explosives known. Great as they are, comparatively speaking, how utterly insignificant they appear when compared with the results of the development of some of the occult sources of power in nature, as illustrated by that gigantic earth-displacement which took place on August 26 and 27, 1883. I refer, of course, to the stupendous upheaval of Krakatoa on the coast of Java, the most formidable volcanic eruption recorded in modern times. It has been computed that the eruption and the tidal wave by which it was followed, swept away at least 50,000 human beings at a stroke. It caused the entire disappearance of an island about 3,000 ft. in height, and transformed the geography of the region of the Sunda Straits. The usual volcanic products including the finest particles, both solid and vaporous, were ejected into the air to a height that no man will ever say, for it is on record that for many miles around the scene of these devastating forces noon was as black as night, and darkness was all over the land for from thirty-six to forty hours. The scale on which the work was done was such that even the noise, the weakest part of it, was heard at a distance of 2,000 miles. The shivering of the island produced a wave of water 100 ft. high, which destroyed everything over which it swept, and left its mark on tidal registers nearly all over the world. The mere air-pulse produced by the last fearful cataclysm was strong enough to pass with its gradually widening circle nearly three times round the globe. It is easy to imagine that, with disruptive forces at work on this gigantic scale, millions of tons of matter, and perhaps millions of cubic miles of vapor, must have been hurled into the upper air. The coarser part of this matter would soon descend, as, indeed, was the experience of the crew of the British ship *Charles Ball*, Captain Watson, which vessel encountered the full force of the downpour of matter, being in the vicinity of the island of Krakatoa. The finely-divided particles, however, doubtless remained in suspension, and were probably the cause of the magnificent sunsets observed all over the world in the November and December following the eruption. Beside the sun-

sets, there was a peculiar appearance of the moon, which had at times a pale green tint, as noticed by myself and others. The remarkable sunsets of 1883 recurred in the autumn of 1884, although not by any means with such intensity and universality. These sun-glows were repeated in the autumn of last year, but with diminished frequency and brilliancy. They have served, however, to keep awake the discussion as to their real nature and cause, but whether they were due to volcanic or cosmical dust, or to some other undiscovered medium, is a point which has yet to be settled, if it ever can be. The theory that they were due to the Krakatoa eruption was not universally accepted at the time it was started; but, in the early part of 1884, M. Angot, in a communication to the French Academy of Sciences, directed attention to a parallel case which occurred in 1831, when there was a violent volcanic eruption, and a new island was thrown up in the Sicilian Sea, together with a quantity of ashes. For some time after the commencement of that outbreak, which lasted altogether for several months, brilliantly-colored sunsets were observable at many places on the Continent.

A singular circumstance is on record in connection with the Krakatoa eruption, which is worth referring to here. On August 26, 1883—the date of the vast upheaval—strange subterranean noises were heard in the island of Cayman-Brac, in the Caribbean Sea. This island is situated in 20° north latitude, and 80° west longitude, and to the South of Cuba. The inhabitants, who are tortoise fishers, were on that day alarmed by noises like the rolling of distant thunder, although the sky was perfectly clear. Seeing no signs of thunder, they imagined that some volcanic eruption was about to take place; but little by little the singular phenomenon diminished, and they ascertained it to be subterranean. Now, the Cayman group are the antipodes of Java, where the eruption took place. The supposition, therefore, that these subterranean noises were due to the Krakatoa volcano at once suggests itself, the disturbance being propagated through the mass of the earth.

Notwithstanding the lamentable destruction of life attendant upon the Krakatoa eruption, it has not been without valuable results to science. Apart from the investigations of sunsets, it led to the correction of many remarkable data in the transmission both of air-waves and water-waves, and with respect to the true nature of volcanic action. A committee was appointed by the Royal Society to collect information as to the eruption, and they have got together a vast amount of information which will doubtless be turned to good account in their report. I recently wrote to the chairman of the committee, Mr. G. J. Symonds, respecting the probable date at which this report might be expected, and he informs me that the members are still hard at work, and that it will be some months before any report can be issued, their labors being so heavy, and in many respects so difficult.

The earth disturbance which occurred in Essex, in the early part of 1884, also yielded some valuable data to science. In fact, were it not for the disasters which these and similar phenomena entail upon humanity, they would be welcomed as important matters for scientific investigation.

But the Java catastrophe, frightful though it undoubtedly was, is not without parallel in the annnals of seismological disturbance. So few of us carry the facts of history in our heads, and so many of us are liable to have our imaginations unduly heightened by such tragic visitations, that we are apt to describe every extraordinary occurrence as unprecedented. It may therefore prove interesting, as well as instructive, if I reproduce from the *Science Monthly*, for January, 1884, a few facts and figures connected with the subject. Taking the number of lives sacrificed as affording the most concise indication of destructive effect of earthquakes in the past, the following approximate figures will help to reduce our most recent experiences to their proper proportions. Confining ourselves to the Christian era, we find that in the year 526 an earthquake in Italy destroyed about 120,000 lives. In 742, again, the greater part of Asia was severely shaken, more than 500 towns were wrecked, and an incalculable number of the inhabitants were killed. India, in 893, was the scene of an equally terrible shock, when, it is said, about 180,000 lives were lost. In 1040, Tabriz

(Persia) was completely demolished, and 50,000 of its inhabitants swallowed up in the ruins. In 1137, one of the earliest of the dreadful Sicilian earthquakes occurred, Catania being overthrown, and 15,000 persons killed. Some thirty-two years later (1169) a similar number perished in Sicily and Calabria. Almost exactly a century afterwards (1268), Cilicia, in Asia Minor, suffered a tremendous shaking, over 60,000 lives being sacrificed. An interval of nearly two centuries now elapsed, the next notable earthquake occurring in 1456, 40,000 of the people of Naples being destroyed by it. Lisbon, in 1531, was almost reduced to ruins, and about 30,000 of its citizens entombed. The following century was remarkable for several most destructive shocks. One occurred at Naples in 1629, when the destruction of life was set down at 70,000 souls; another took place in Russia (1667), the victims numbering 80,000; and the most terrible of all happened in Sicily (1593), more than 100,000 persons perishing.

The eighteenth century opens with the destruction of Yeddo, in Japan, and 200,000 of its inhabitants (1703). Only three years later, Naples suffered another of its many shocks, 15,000 perishing on this occasion. Algiers was the scene of several earthquakes in 1616; victims, 20,000. In 1727, Tabriz was again demolished, and 77,000 persons destroyed. The city of Pekin was leveled with the ground in 1731, about 100,000 Celestials being killed. In 1755 occurred the celebrated Lisbon earthquake, which seems to have marked a period of great seismological activity, shocks being frequent and severe in all the volcanic regions of the globe about that year. The total number of persons who perished between 1754 and 1756 must have been hundreds of thousands. A calm followed the storm, for the latter half of the century was comparatively free from disturbance; but 53,000 lives were destroyed in Japan in 1793, and shortly after, when the city of Quito, in Peru, was overthrown, 40,000 lives were lost. Coming nearer our own time, we find a destruction of 26,000 lives in Italy in 1805; 12,000 in Venezuela (1812); 20,000 at Aleppo (1822); 7,000 at Algiers (1825); 10,000 in St. Domingo (1842); 14,000 in Italy (1851); 10,000 in Persia (1853); 30,000 at Yeddo (1855); 15,000 in the Argentine Republic (1861); 10,000 in the Philippine Islands (1863); 25,000 in Central America (1868); and 14,000 in Chili (1875).

As I have already stated, these figures are only approximate, and, in fact, the whole record is somewhat barren, and affords but a poor idea of the destructive earthquakes of history. It has been computed that at least 7,000 shocks must have been experienced within historic times. Many of these have destroyed, not thousands merely, but tens of thousands of human beings; hence, the actual victims in all ages must be many, many millions. But the point here is, that the least of these eruptions utterly eclipses anything in the way of earth-dislodgement ever attempted by man.

Regretable, however, as are such occurrences as those to which I have just referred, they carry with them some consolation. They may even be said to have their bright side, inasmuch as they indicate that our earth still possesses life and vigor. In this respect the earth presents a marked contrast to the moon, some fine photographs of which I saw a short time since, and which presented it to the eye as the embodiment of sterility and desolation—a magnificent spherical clinker. Science has revealed to us the fact that the moon is absolutely dead; that it has not sufficient life left to ooze forth the tiniest mud volcano or to spurt out the feeblest geyser; that no throb ever reaches its surface, and that not the faintest rumble is ever echoed from its jagged mountain sides. No earthquake wave can ever sweep its face, for earthquakes there are things of the almost infinite past; the last drop of water quitted its valleys ages ago, and its very atmosphere has deserted it. Not even the 600° heat of the sun, which beats upon every part of the moon for a fortnight at a time, is able to quicken into life one atom of its mass, which, according to Professor Langley, has a temperature lower than that of melting ice. Everything goes to show that, at a time, its volcanic activity must have been of the most stupendous kind, far exceeding anything yet witnessed on this earth. But that has gone with its water and its atmosphere, and it is difficult to realize the fact that when we gaze upon its effulgent loveliness, we look upon what is,

physically speaking, a charred and blackened corpse. That the earth has not yet lost its vigor is proved by the Java catastrophe and by subsequent similar minor manifestations. Moreover, we are told that so long as the old earth is equal to efforts of this kind, we need not fear its end; but that, when volcanoes and earthquakes cease from its face, the end may be within almost measurable distance. Much of its ocean water will have been absorbed by the underlying rocks, and the atmosphere may be rarer and less life-supporting than it is now, until at length, with the last atom of internal heat, the last drop of water and last particle of air, all life will have vanished and a dead earth will shine upon a dead moon.

I next proceed to notice the present advanced position of the science of engineering—which lays under contribution so many other sciences—and of our own profession, which puts that science into into practice. It is admitted on all hands to be a great science and a noble profession. It has compassed mighty purposes, has accomplished great ends, and, I cannot doubt, is destined to accomplish greater yet. Born, as it has been, of the present century, in fifty years the engineering profession has practically overrun the face of the whole earth, materially altering its physical appearance and condition. Seas have been united, countries have been divided, and continents have been spanned by the engineer, whilst lasting monuments of his power and skill dot the sea as well as the land. It is only repeating a truism to say that fifty years have produced great and marvelous changes in almost everything that pertains to life, thanks to the engineer. Even life itself is now due to conditions which did not exist fifty years ago. Where, at that time, disease was rife, and in many cases death inevitably stepped in and prematurely claimed its its prey, the sanitary engineer has successfully intervened, and has removed the cause and prevented the effect. Where, at that time, months were occupied in transmitting news to the other side of the globe, seconds now suffice, with the aid of the electrical engineer, to flash intelligence to and from the uttermost parts of the earth. Where, at that time, it took the lumbering old stage-coach days to accomplish a journey to the North at an average speed of ten miles an hour, the locomotive, thanks to the mechanical engineer, now takes us the same journey in a few hours at a speed of from fifty to sixty miles an hour; and, lastly, where, at that time, a few hundred copies of a newspaper were all that, at the best, could be produced in an hour, and those on detached sheets of paper, in the present day, thanks to Mr. Walter, of the *Times*, and also to the mechanical engineer, they are printed at the rate of thousands per hour, the paper being continuous and miles in length. In all this there is no idle boasting, it is but a simple statement of incontrovertible fact. And, if we stopped at a statement of fact, I might have nothing more to say upon the subject. But do we always so stop? Is there not rather an occasional tendency, both with writers and speakers, to magnify our times at the expense of former ages? I think there is. Not many years since, a prominent member of the profession expressed his regret at the non-existence of engineers 500 years ago. If he meant engineers as members of a recognized professional body, engineers of the present type, men who construct railways, manufacture steam-engines and machinery, and build ironclads and steel ships, his regret is intelligible. But even then, honestly speaking, he should have little cause for regret, inasmuch as the whole available surface of the earth might long since have been so completely engineered as to have left him no opportunity to have distinguished himself. He might then have wished that there had been no engineers 500 years ago. But, were there no engineers at that time? To take one instance only, one of the most important branches of mechanical engineering in the present day is that relating to the manufacture of artillery. It is a matter of history that cannon were first used in warfare at the battle of Cressy, which took place in 1346, and by the Moors in the defence of Algeziras, about the same period. Surely the manufacture of artillery was relatively of as great importance in the reign of Edward III. as in that of Queen Victoria, and those who carried on that manufacture are as much entitled to be considered engineers as those who manufacture the

100-ton guns of the present day. Perhaps more so, if we judge them by their light, and take into consideration the disadvantage at which they were placed as compared with their successors in the craft, who, with all their ingenuity and experience, and with all the materials and machinery at their command, manage to have a gun burst accidentally now and again. I know it may be urged that the guns of old were very small weapons. There is, however, one example still extant, of a more recent date, it is true, but of somewhat remarkable size and construction for the period at which it was produced. I refer to the celebrated Mons Meg, in Edinburgh Castle. This gun is said to have been manufactured at Mons, in Belgium, in 1476, whilst others hold that it was made in Galloway, and was used by James II. at the seige of Thrieve Castle, in 1455. It is, however, known to have been employed at the the seige of Dumbarton, in 1849, and at that of Norham Castle, in 1497. It burst when firing a royal salute in 1682. The gun is 13 ft. long by 20 in. in diameter, and is formed of longitudinal bars of wrought iron, encircled by hoops of the same material, its weight being five tons.

As a matter of fact, however, the "five hundred years ago" was merely an arbitrary definition of time on the speaker's part, for his remarks were intended to apply to the long past in general, and to imply that engineers were a race of men unknown to any time but the nineteenth century. The expression was, in fact, begotten of the spirit which, as I have observed, would fain magnify the present to the depreciation of the past. When we indulge in this view we surely forget the broken arches of the huge aqueducts and bridges which cross the Campagna, and which ought to remind us of the engineers whose names history has failed to preserve. Those who have forded rivers by the Roman paved paths, or who have driven for miles along the firm Prætorian Ways, which, 2,000 years ago, the conquerers of the world constructed for the march of their legions, might even doubt whether Telford, Macadam, and their successors have made any very great advance on their predecessors on the art of road-making. The Cloaca maxima was a sanitary institution which we have yet to imitate. The palaces and sewage arrangements of Nimroud, the hanging gardens of Nebuchadnezzar, the canal which Xerxes cut across the isthmus of Mount Athos, were, like the bridge of boats with which he spanned the Dardanelles, engineering works which we should all do well not to utterly ignore when we would exalt ourselves and our times in these respects. The men who reared the Pyramids, and who erected the monoliths of Egypt, possessed an art which died with them. It is, moreover, not a little singular that in the past, nations which are sometimes credited with having possessed no knowledge of science, have produced the most beautiful structures. The Mahommedans and the Hindoos, ages ago, without text-books, so far as we can learn, without scientific schools or rules to guide them, stumbled into the creation of those charming edifices which it is one of the privileges of Eastern travelers to see. That they were guided in some sort by scientific principles, we cannot doubt. and although we may not be able to discover them, are we justified in ignoring them? And how far back into the remote past can we peer in the vain hope of catching a glimpse of these workers at their early labors? Where is the page of history that discloses to us

"A race who carved the temple of the sun,
And mighty fanes from out the living rock;
Fanes which lay mouldering, o'erthrown by time,
While yet the pyramids were not."

We may exhaust tradition, and still find ourselves no nearer the time when such science as they had was flourishing at its best. The stupendous cavern temples of Nubia and upper Egypt proclaim an antiquity in the contemplation of which all tradition is lost sight of. The researches of some of our modern explorers lead to the conclusion that the most ancient buildings of the Thebaid, especially the great temple of Karnac, which had a circuit of a mile and a-half, are, to a large extent constructed of the materials of edifices themselves as ancient when they were thus dismantled as those which are now standing have become since their demolition. Thus we have come to be aware that the antiquity of a civilization so remote that tradition scarcely reaches to the latest epochs

which its monuments illustrate, is at least doubled by the evidence of those monuments themselves.

And here I may refer to the fact that early in 1884, fresh proofs of the existence of an ancient civilization in Mexico were discovered in Sonora, about sixty miles south-east of the town of Madeleine, where some explorers found, in the heart of a virgin forest, a pyramid, which is 4,350 ft. round the base, and 750 ft. high, that is, nearly double the size of the great pyramid of Cheops. From the base to the summit there is a roadway on which vehicles can travel around the vast erection in a spiral. The outside walls are built of granite blocks carefully tooled and bedded. A little further off is a hillock, with hundreds of caverns or chambers cut in it, from 5 to 15 ft. wide and 10 to 15 ft. long. They have no windows, and are entered by the roof. The walls are covered with hieroglyphics and curious pictures, with the feet and hands of men. Stone utensils have also been found there. Who the builders of these ancient monuments were is still unsettled, but they probably belonged to the Mayos, who formerly inhabited Sonora, and were a different race to the Indians, having blue eyes, a white skin, and blonde hair.

The key-note to the favorable results of a comparison instituted between the works of the ancient and the modern engineer, as against the former, is undoubtedly scientific progress and development in its broadest and fullest sense. The bridges with which Robert Stephenson spanned the St. Lawrence and the Menai Straits are, as efforts of skill, infinitely beyond anything that Roman perseverance could accomplish. In like manner the simple contrivance by which George Stephenson succeeded in carrying the Liverpool and Manchester railway across Chat Moss, manifests a genius for a corresponding display of which, in the works of the ancients, we search in vain. Their works astonish us by their vastness, by their magnificence, and by the expenditure of brute force which must have accompanied their construction. Those of the moderns aim at introducing lightness and elegance of design, and economizing material and power, and they have to be examined in detail before their full merits are apparent. Take the magnificent bridge over the Firth of Forth, the works of which I recently had an opportunity of inspecting, and which twice span 1,700 ft. of sea at a stretch, at a height of 150 ft. above high-water level, with its cantilevers towering 200 ft. higher, and examine its details. In their minuteness and relative correctness with regard to each other and the whole structure, they are such as never could have been conceived by the ancients. Size and massiveness with them went hand in hand, resulting in an appearance of grandeur typified rather by the Egyptian style of architecture than by the modern Gothic. We should endeavor so to combine size with lightness, as to produce an appearance of elegance. Art and science, beauty and utility, when rightly understood, are never in conflict, and they can be as perfectly in agreement in a chimney stack in Manchester as in the beautiful Gothic of Milan Cathedral. The happy blending of true æsthetic principles with the more rigid and circumscribed requirements of utility in constructive art, cannot fail to produce what that gifted artist Von Schlegel has so beautifully described as "frozen music."

But if we reduce the design of Forth Bridge to first principles, what do we find? Simply that it is a development—a very grand one, it is true—of a rude kind of structure raised by the inhabitants of Thibet, Cashmere, and the mountains of India, consisting of beams projecting from piers. Each beam is made to project beyond the one that supports it, until the two sides approach sufficiently near to admit of a beam being laid across to connect them. Here we have a rude plan which has been converted into a scientific and beautiful method of construction by engineering science. The old semaphore system of signaling, which for years many of us were accustomed to see at work on the roof of the Admiralty at Whitehall and elsewhere, was of more imposing appearance than a thread of telegraph wire with a Morse sending instrument at one end and a Wheatstone automatic receiver at the other. But how incomparably superior to the former is the latter! Again, look at our glorious Nelson's ship, the *Victory*, in Portsmouth Harbor, and compare her with a modern torpedo-boat

steaming past her at 22 knots an hour.* The contrast in size is striking, but the contrast in power in proportion to size is simply startling. The one would hardly make a cock-boat for the other, although whilst the ancient engine of war was changing her course but a few points the modern machine could come upon her, deliver its deadly message, and steam well clear of the vortex caused by the sinking three-decker.

I have said that the key-note to the advanced position of the present age is scientific progress, and I now desire to direct your attention to the circumstance that the principles involved in and underlying several of the most recent developments of science which constitute that progress were not unknown to some who lived in bygone ages. But although they appear to have been conversant with those principles, they lacked the power of giving practical effect to their knowledge. It is the possession of this power —this civilizing quality—and its legitimate utilization which have led to the remarkable developments of modern times. The scant records of the past have for the most part only brought down to us the theories of the ancients in such a vague form as to cause them to be passed by as the utterances of visionaries or the fantastic day-dreams of poets, unless, perchance, a train of thought should establish a connection between what may be regarded as the prophecy and its fulfillment. Take, for example, electrical telegraphy, which forms one of the practical adaptations of that latest-born daughter of modern science —electricity. Many of us are in the habit of unthinkingly associating with its invention the honored names of Cooke and Wheatstone, so prominent is their position in this connection, and so important the part they played. Great, however, as was their work, they only took up and perfected that of many others, their predecessors, whose labors led up to their victory. The electric telegraph had, properly speaking, no inventor; it grew up little by little, each inventor contributing his share towards its advancement. At least a score of names adorn the roll of fame in this respect. Commencing very nearly a century ago with those of Galvani and Volta, we encounter in our run down the stream of time, the names of Sömmering, Schweigger, Coxe, Romagnési, Oerstadt, Ampère, La Place, Fechner, Alexander, Sturgeon, von Cannstedt, Faraday, Morse, Gauss, Weber, and Steinheil, each of whom contributed successively a round in the ladder which was ascended by Cooke and Wheatstone. These latter, however, were the first to establish a telegraph for practical purposes on a comparatively large scale, and thus their names came into prominence, whilst those of Ampère, von Cannstedt, Steinheil, and others remain comparatively unknown in this immediate connection.

In referring to Galvani and Volta, I have looked back a hundred years to what appears to be the first conception of the idea of an electric telegraph. The means of attaining this end, however, may have been struggling for birth in reflective minds for many centuries past, for aught we know. In support of this, let me go back two centuries and a-half to the time of Galileo, who appears to have been fully aware of the importance of employing magnets for transmitting intelligence to a distance, although he did not see his way to the practical accomplishment of his idea. In one of the dialogues which he wrote in 1632 on the two great rival astronomical systems, he makes one of his myths, Sagredus, to say, "You remind me of one who offered to sell me a secret art, by which, through the attraction of a certain magnet needle, it would be possible to converse across a space of two or three thousand miles. I said to him that I would willingly become the purchaser, provided only that I might first make a trial of the art, and that it would be sufficient for the purpose if I were to place myself in one corner of the sofa, and he in the other. He replied that in so short a distance the action would be scarcely discernible; so I dismissed the fellow, and said that it was not convenient for me just then to travel into Egypt or Muscovy for the purpose of trying the experiment, but that if he chose to go there himself I would remain

* In the speed trials of two torpedo boats recently built by Messrs. Yarrow & Co., when the boats were loaded with 17 tons (representing the fighting trim), the speed obtained was 22¼ knots an hour, and when tried on the light water-line, 24 knots, which is equal to 27⅓ statute miles an hour, being the highest speed on record.

in Venice and attend to the rest."* Whether the idea originated with Galileo or with another who communicated it to him is not certain; but what seems perfectly clear is that in this dialogue we have the first absolutely defined conception of the electric telegraph. This interesting fact was pointed out to me some years since by an old friend, Mr. Richard Bellamy, a gentleman of considerable erudition. He also communicated it to Mr. Robert Sabine, who introduced it in the preface to his "History of the Electric Telegraph" in Weale's Rudimentary Series. Again, take the case of lightning conductors. Here we find that Franklin was probably anticipated in his discovery of lightning conduction. According to M. de Rochas, the ancient Etruscans understood the art of guiding lightning. Servius relates that in ancient times the priests ignited their sacrifices by lightning, and upon one occasion Tullius Hostilius was struck dead because he neglected the precautions laid down by Numa.

Turning to surgical science, let us take the circulation of the blood. The discovery of this wonderful principle was undoubtedly enunciated by Harvey in the early part of the seventeenth century, namely, in the year 1619. But I have read a very striking description of the circulation of the blood in a book which was written 2,600 years before Dr. Harvey's time. It is possible that Harvey may have read it too, and that, as a medical man, it may have suggested to his mind a research in the direction in which he eventually made his great discovery. It is also possible that, like thousands upon thousands of others, he may have merely read it, and have considered it a piece of poetic imagery bearing some occult meaning known only to the writer, and never further developed by him. In fact, like Wordsworth's Peter Bell—

> "A primrose by a river's brim
> A yellow primrose was to him,
> And it was nothing more."

I refer to that beautiful description of the decay, by reason of age, of man's natural powers, written by Solomon at the close of the Book of Ecclesiastes, in the year 977 B. C., or nearly three thousand years ago. He describes the dimming of the various faculties, under exceedingly poetical but equally appropriate and unmistakable symbols, and he goes on to say: "Or ever the silver chord be loosed, or the golden bowl be broken, or the pitcher be broken at the fountain, or the wheel broken at the cistern."* Here, then, we have the silver chord—the spinal marrow, the golden bowl—the heart, the pitcher at the fountain and the wheel at the cistern—both representative of the means by which the Easterns obtained and still do obtain water, and in conjunction with the golden bowl, clearly symbolizing the circulation of the blood.†

Another cognate matter is the comparatively recent discovery of those minute entities known as bacteria. I fear we can only call this a re-discovery, inasmuch as two centuries ago the celebrated naturalist, Leeuwenhoek, with wonderful skill, considering the very imperfect instruments of his time, anticipated modern physicists in this connection. The discovery of this circumstance is due to Professor E. Cohn, of the University of Breslau, who, a year ago, in a communication published in the *Allgemeine Handelsblatt*, recapitulates the substance of a correspondence of Leeuwenhoek with Francis Aston, of London, a member of the Royal Society. Leeuwenhoek, writing from Delft, in 1683, reports that among the *debris* of food remaining between his teeth he had discovered, with the aid of the microscope, living organisms moving with great activity. He distinguishes various kinds among them, which he describes so precisely that they are easily recognizable. One, which occurs least frequently, resembles a rod, the bacilus; others, twisting in curves, are bacteria; a third kind, creeping in snake fashion, is the vibrio ugula; another kind, of extreme minuteness, resembles a swarm of flies rolled up in a ball, and is evidently the micrococus; its movements cannot be traced with certainty. He says that this species seems to be made up of parallel threads varying

* "Galilei Systema Cosmicum," Dialogue I., Leyden edition, 1700.

* Ecclesiastes xii. 6.

† The "sakia," or Persian wheel, or the "natura," as it is called in some countries, is the great instrument of irrigation in the East. It consists of an endless chain formed of twigs, and strung with earthen pitchers. The chain passes over a wheel driven by oxen, and the pitchers raise the water from the well, and deliver it into a cistern.

in length, and remaining immovable, while other specks move in and out through the web. Leeuwenhoek marvels that these things could live in his mouth, notwithstanding his systematic habit of cleansing it. He instituted observations which showed that they were also to be found in the mouths of other persons. Some years later he could not discover any traces of those minute organisms, and he was lead to attribute their disappearance to the use of hot coffee. But shortly afterwards he rediscovered them as lively as ever. In September, 1692, he sent some sketches of them to the Royal Society. From this correspondence, it would seem that the knowledge concerning bacteria made no advance for nearly two centuries, but it clearly places Leeuwenhoek in the position of their original discoverer.

Quitting medical science, let me turn to that which relates to the production of our modern weapons of war and our most cunning devices for endeavoring to deprive our enemies of the pleasures of conquest. Here we have one who was both poet and seer, most distinctly foreshadowing the submarine traveling torpedo. This was Ben Jonson, who, in his play, "The Staple of News," wrote, in act. iii. scene 1, as follows:

THOMAS.

They write here one Cornelius' son,
Hath made the Hollanders an invisible eel
To swim the Haven at Dunkirk and sink all
The shipping there.

PENNYBOY.

But how is't done?

CYMBAL.

I'll show you, sir.
It's an automa, runs under water
With a snug nose, and has a nimble tail
Made like an augur, with which tail she wriggles
Betwixt the costs of a ship and sinks it straight.

PENNYBOY.

A most brave device
To murder their flat bottoms!

What, therefore, to the playgoers of Queen Elizabeth's time was the most palpable absurdity a poet's fancy could invent, is to us simply an accomplished scientific fact. In like manner, Dean Swift, 160 years ago, credited the astronomers of Laputa with the discovery of two satellites revolving about Mars, whilst the actual discovery of Mars' moons did not take place until about the year 1877.* These are, to say the least, curious coincidences, and however much Ben Jonson's "invisible eel" may have been the offspring of poetical fancy, and however little Swift's moons may owe their origin to astronomical knowledge, the fact remains that we have two distinct scientific forecasts which have been singularly verified in our own times. Even more remarkable than either of the foregoing is the poet William Drummond, of Hawthornden, who, 260 years since, did not simply shadow forth at the bidding of the muse what might then appear an absurdity or a quaint conceit, but in very precise language indicated some of the most important weapons of war used by the armies and navies of the civilized world in the present day. Looking through the records of the Patent Office some years since for information upon a cognate subject, I came across a specification entitled "The Letter of Master William Drummond for the Construction of Machines, Weapons, and Engines of War for Attack or Defense by Land or Sea, etc.," and dated September 29, 1626. In this remarkable document no fewer than sixteen inventions are apparently included, although only fifteen are indicated. The first is described as an instrument for cavalry use, by which a single man can be of no less avail in battle than five or six with the ordinary weapons. It is called a "box-pistoll" and a "muskett-box," and its effect is said to be at once terrible and rapid. This invention appears to answer to the repeating rifles and revolvers of our time. The second invention is described as a "shooting-spear," for a musketeer, and was probably a blade attached to the musket, as is the bayonet in the present day. The third invention is a number of musket barrels fastened together, and called a "lightning chariot," which would appear to be the prototype of the mitrailleur and Gatling gun of modern warfare.

* "They have likewise discovered two lesser stars, or satellites, which revolve about Mars, whereof the innermost is distant from the center of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of two hours, and the latter in twenty-one and an half; so that the squares of their periodical times are very near in the same proportion with the cubes of their distance from the center of Mars, which evidently shows them to be governed by the same law of gravitation that influences the other heavenly bodies."—*A Voyage to Laputa, etc.*, edit. 1755.

The fourth invention is described as one from which three, four, or even five balls were to be fired in the same time as a single ball, and from the name given to this appliance of "open ordinance" it would seem that modern breechloading artillery was foreshadowed.

The sixth and seventh inventions relate to guns, one of which is called a "flatscourer," and the other a "cutter,' the inference being that the use of chain shot was here intended. The seventh invention is a movable fort or turret for soldiers. The eighth invention is omitted from the original document, nor is there any clue as to its nature. Now it is just possible that this missing invention may have been the one imported by Ben Jonson into his play, and I will give you my reasons for thinking so. I find that Jonson visited Drummond at Hawthornden in the spring of 1619, and the latter may then have communicated his ideas in this respect to the former. Jonson's wit would readily transform the more sober notion of Drummond into satire, and this might prevent Drummond with his more sensitive nature from making public the original of Jonson's ludicrous automaton. As tending somewhat to prove the correctness of my assumption, I would remark that the ninth is in some sort a cognate invention with Jonson's "automa," inasmuch as it is described as "a new sort of ship which can enter ports of any sort, even barricaded by powerful chains, bars, or engines, and can destroy whole ships by fire or forcibly capture them." "The ship," continues the specification, "from its immense and really terrible effect, and its tremendous destruction of ports and ships, deserves to be called 'Leviathan.'" This would appear to embody the idea of our modern ships of the ram class.

Here Drummond appears to have exhausted his stock of invention as regards the arts of war, and he turns his attention to those of peace, for the tenth item is an instrument for measuring the speed of the wind, or of a ship, in fact, an anemometer and a log combined. The eleventh invention is a "sea postilion," which in some respects answers to our little steam launches. The twelfth invention is worthy of note; it is called a "lenth-compas, by which the distance of a voyage may be exactly calculated, and the different longitudes, either at sea or on the nearest shore, determined." Now here we apparently have the first suggestion of a means of discovering the longitude of ships at sea. The patent, as I have said, is dated 1636, and it was not until 1674 that a Frenchman—St. Pierre—submitted to Charles II. a method of effecting this object. The proposition was referred to a committee of astronomers, of which John Flamsteed—the first astronomer royal of England—was a member. Flamsteed drew attention to the incorrectness of the lunar tables by which the position of the moon amongst the fixed stars was to be calculated. Struck by the deficiency, the monarch is said to have at once founded the Observatory at Greenwich, which was called Flamsteed House. The king appointed Flamsteed to the post of astronomer royal, at a salary of £100 per annum. It does not appear that previously to this any attempt had ever been made to determine the longitude of a ship while at sea. To return to Drummond, I have only to notice that his thirteenth invention was a still for rendering salt water potable, whilst the fourteenth and fifteenth have reference respectively to burning-glasses and telescopes, or "lynxes eyes," as he calls them. In the sixteenth and last invention Master Drummond falls foul of that *pons asinorum* of inventors of all times—perpetual motion—for he describes it as "a machine producing perpetual motion from a natural cause, and one incapable of fatigue, by the employment of whose aid a variety of mechanical operations may obtain motive power, and it is called 'momet.'" Such is the poet's remarkable list of inventions, which I need hardly say embraces a far greater variety of subjects than could be coaxed into a single patent in the present day, especially under the new law. The inventions are not in any case described in detail, nor does Drummond illustrate them, a course which some inventors of our own time would like to be permitted to pursue. Neither am I aware of Drummond having carried any of his inventions into practical effect. Of course, breechloading arms are by no means so modern an invention as is generally supposed, as the relics in the Tower of London show. Possibly some of these might be traced to Drummond's

patent, although this is very problematical. Be this as it may, there is no question that those of his inventions which relate to the arts of war do certainly foreshadow many of those at present in prominent use, and which are regarded more or less as distinct creations of our own times. As it may occur to some that they have come across this somewhat singular disclosure respecting Drummond before, I may here mention that the matter formed the subject of an article from my pen which appeared in the leading journal some nine years since.*

Before quitting the region of prophecy and fulfillment, I would observe that England's greatest poet—Shakespeare—appears to have placed himself in the same category as Jonson and Drummond. In the second scene of the fourth act of "Troilus and Cressida," Shakespeare makes Cressida say—

> "But the strong base and building of my love
> Is as the very center of the earth,
> Drawing all things to it."

To my mind the poet here most clearly anticipates Sir Isaac Newton's great discovery of gravitation.

I have taken you back with me a long way into the past, not merely to prehistoric times, but I have even exhausted tradition. It must not, however, be assumed from this that I live in the past. I live in the present, and for the future. I obey the poet's behest, which is to

> "Look back upon the past, and by the lights
> Which now are thine, onwards towards the future."

Let us see, then what the facts I have adduced teach us. I think they show us that what was aforetime spoken hieroglyphically and in fable is now being spoken plainly. In fact, the idealism, the imagination of a bygone age has in more instances than one become transformed into a reality in the present one. The dream of the poet, and the inchoate indefinite idea of the sage of antiquity have become materialized, and produce the daily bread of the artisan. That which was once purely spiritualistic, and which formed one of the highest elements of fiction—communication and identity of thought without sense of distance—has become strangely realistic, and is inextricably interwoven with the web of ordinary everyday life. It is, however, one thing to have a vision, but quite another to be able to give it form; one thing to conceive, but quite another to invest the conception with practical existence. But in the past, when knowledge was power of an oppressive and tyrannical character, a veil of impenetrable mystery was drawn around the early germinations of science by her bigoted votaries. The pursuit of knowledge was only permitted to the few, whilst the mass wondered ignorantly on in mingled terror and admiration. Hence it is reasonable to suppose that there were in former ages developments of science which ran parallel with some of our own—in fact, I have to some extent shown this to have been so—but they were most jealously guarded, and have been buried with overthrown nations. We may also learn a lesson of patience and unresting, but not restless, perseverance in our work. Great results are not achieved in a day, or, as Smiles appropriately puts it, "great inventions are not brought forth at a heat." They are begun by one, improved by another, and perfected by a whole host of successors.

The facts I have brought before you also point to the moral and material progress of the world. "The bee that hummed its busy hour through the bowers of Paradise," wrote Sydney Smith, "fashioned its hexagon with the same mathematical precision which it does now and here. Six thousand years have added nothing to the sagacity of the horse or the intelligence of the dog." But how widely different with man! He commences as a fire-worshiper and rises to a Newton, a Faraday, a Stephenson, a Siemens. Tempts the river in a few fragments of bark lashed together with thongs of raw hides, and crosses the Atlantic in an iron steamship of 22,500 tons burthen.† Burrows in the earth, and then builds a city with four millions and a-half of inhabitants. Sticks a dried reed in a lump of fat to light his mud hut, and carbonizes 2,200,659 tons of coal per annum to illuminate London.‡ Takes weeks to send mes-

* *Times*, November 29, 1877.

† The *Great Eastern*.

‡ During the year 1884 the Chartered Gas Company carbonized 1,568,821 tons of coal; the South Metropolitan Gas Company 457,637 tons, and the Commercial Gas Company 174,201 tons; total, 2,200,659 tons.

sages on sticks to Montezuma, from the coast, and at last reports in London the details of a battle fought in the Soudan the same morning. Slays his foe with a sling and a pebble chosen from the brook, and meets the enemy with a machine-gun firing 600 rounds a minute by means of its own recoil.* Lays seige to a city with a balista, throwing a fragment of rock, and finally attacks a fort with a gun weighing 110 tons, projecting a steel shell of 1,800 lbs., with a charge of 900 lbs. of gunpowder. The axe-head that floated for a few seconds on the Jordan three thousand years ago, when "the iron did swim," was a miracle indeed; but what of the hundred of thousands of tons of iron that are now continually swimming over our seas in masses some thousands of tons each?

These are extremes, and they stand very wide apart. But they are to-day the beginnings and the endings of science, and thus stated, they bring out in bold relief the contour lines of progress. But they are the endings of science as regards the present only. They are by no means final, or science never stands still. They are but the landmarks of our times, which, as Emerson puts it, are "trivial to the dull, tokens of noble and majestic agents to the wise; the receptacle in which the past leaves it history; the quarry out of which the genius of to-day is building up the future."

The progress of science, however, is very far indeed from being measured or measurable by its material achievements. It has done infinitely more than merely give us railways, telegraphs, arms of precision, and other practical applications of its discoveries. What it has further done I cannot express better than in the words of a recent anonymous writer, who says: "It has given to the human race, for the first time, standards of truth which are at once absolute and accessible, and has thus caused a knowledge of truth, of its tests and evidences, and an engrossing love it, to become the chief mental characteristics of those who are really engaged in it. Great as have been the material rewards of science, the moral rewards will be greater still." The opportunities of scientific education, which are daily increasing in our midst, must hasten the coming of the time when these moral rewards shall be within the reach of all who will stretch forth the hand to grasp them.

* The Maxim gun.

TRIPLE EXPANSION ENGINES.

From "The Engineer."

THE literature of the triple expansion engine is at present extremely limited. Indeed, all that has been written on the subject might be put within the covers of a very small volume. It is comprised in certain papers read before engineering societies, and articles which have appeared from time to time in our own and other technical journals. It is with the more pleasure, consequently, that we have read a pamphlet, "Etude sur les Machines Compound à Triple Expansion," by Mons. Maurice Demoulin, and published by Messrs. Baudry & Co., Rue des Saintes-Pères, Paris. The position held by Mons. Demoulin with the Société Ateliers et Chantiers de la Loire, has enabled him to write with a competent knowledge of his subject, and we can strongly recommend the work to those of our readers interested in steam navigation. It is not our intention to review the pamphlet here, but it contains some statements the accuracy of which seems to us to be open to question. These statements have not, we think, originated with Mons. Demoulin, and his responsibility for them is perhaps one of adoption only.

It is commonly assumed that one of the reasons, if not the reason, why the compound engine is more economical than the simple engine, is that the range of temperature in the cylinders is smaller. As Mons. Demoulin puts it, the condensing power of the cylinders of a compound engine is less than that of the cylinder of a simple engine; and he gives a table illustrating this theory by a prac-

tical example. No doubt to a certain extent he is right. He assumes an initial pressure of 127 lbs. per square inch, a back pressure of 4 lbs., and a total range of expansion 10. He then states the case for three different engines of the same power. The first has a single cylinder, with a stroke of 1 meter, and a diameter of 1.5 meter; the second is a compound engine, with a stroke of 1 meter, a high-pressure .75 meter, and a low-pressure cylinder 1.5 meter in diameter; and lastly, a triple expansion engine, with a stroke of 1 meter, and cylinders .61, .96, and 1.5 meter diameter respectively. He multiplies the surface in each cylinder by the range of temperature in it, and adds all the products together, getting as the coefficient of condensation in the single-cylinder engine, 895.98, in the double-cylinder 686,34, and in the triple expansion 585.06, showing an advantage of 15 per cent. possessed by the double over the single-cylinder, and 34 per cent. possessed by the triple cylinder over the first. This calculation is based on the amount of surface in each cyliner. The large cylinder is the same in all the engines. Its diameter is 59 inches; its condensing surface, allowing for clearance, will be 7,412 square inches for the cylinder walls, and 10,932 square inches for two piston faces and two covers, or 127.3 square feet. We have made no allowance for passages or piston-rods; yet Mons Demoulin makes the surface only 8.22 square meters, or 88.5 square feet. Multiplying 127.3 square feet by the range of temperature due to a fall of pressure from 127 lbs. to 4 lbs., we have 24,441, in round numbers, as the coefficient of condensation of the single-cylinder engine. In the triple expansion engine the high-pressure cylinder has a surface calculated in the same way of 33.5 square feet, but Mons. Demoulin makes the surface only 26.88 feet. The intermediate cylinder has by our calculations a surface of 64 square feet; by Mons. Demoulin's, 46 square feet. He assumes the fall in pressure in the first cylinder to be from 127 to 50 lbs. The range of temperature is 64 degrees. The fall in the intermediate cylinder he assumes at 50 lbs. to 21 lbs., or 51 degrees, and for the low-pressure cylinder 21 lbs. to 4 lbs., or 77 degrees.

Multiplying the areas by the ranges of temperature, we have for the high-pressure cylinder $33.5 \times 65 = 2177$ as its coefficient of condensation. For the intermediate cylinder we have $64 \times 51 = 3,264$, and for the low-pressure $127.3 \times 77 = 9,802$. Summing up, we have 15,243 as the coefficient of condensation in the triple expansion engine, a result different from that given by Mons. Demoulin. It seems probable that he has in his calculations forgotten to include the surfaces of the pistons, which are quite as potent for condensing purposes as the surfaces of the cylinders. The influence of the passages is also very considerable, especially in some types of engine, in which the ports are very long; the high-pressure slide being some way from the cylinder, as, for example, in the engines of the Arabian, an excellent lithograph of which is given by Mons. Demoulin. Indeed, the proportion borne by port and valve surface to that of the cylinder is often very large, and ought not to be neglected. His calculation is also to some extent invalidated by the fact that he has in all cases taken the terminal pressure in one cylinder as the initial pressure in the next, which it never can be. The range of temperature in each cylinder will therefore be less than he has made it, so that he has sacrificed a point in his own favor, balanced, perhaps, by the circumstance that inasmuch as there is a continual rise and fall of temperature in the intermediate receiver or receivers, there is probably condensation and re-evaporation going on there, of which he has taken no notice.

All calculations of this kind are, however, vitiated by the remarkable fact that condensation in the high pressure cylinder of a triple expansion engine is known to be not less than that which takes place in the single-cylinder engine. It is not, perhaps, easy to explain the cause. It is possible, however, that the whole body of steam comes more freely in contact with the metal of the small than can be the case with a large cylinder. It has, at all event, long been known that the efficiency of a jacket augments as the diameter of the cylinder decreases, and this can only be because cylinder condensation diminishes as the diameter of the cylinder is increased. It matters nothing, be it understood, how initial condensation takes place, so long

as it does take place. That is to say, the loss of efficiency would be the same whether part of the condensation took place in each cylinder of a triple engine or all in one. The boiler does not know what becomes of the steam, and if, as is sometimes the case, over 40 per cent. of the whole is condensed in the high-pressure cylinder, the loss falls directly on the boiler, and will be the same as though 40 per cent. had been condensed in a single-cylinder engine. But it is very well known that, be the condensation what it may, the resulting water does not to the end remain water in the engine. A portion, at all events, is sure to be re-evaporated. The economy of the compound engine depends on the fact that the resulting steam is used expansively in the second, or in the second and third cylinders. Mons. Demoulin recognizes this himself, for he says:—"Les moteurs à detente multiple doivent leur supériorité économique, en partie aux causes que nous avons signalées, en partie á un fait tres important qui, jusqú'á nos jour, a echappé á la plupart des savants et des ingénieurs, et qui consiste en ce *la vapeur condensee au petit cylindre agit, apres sa réévaporation, sur les pistons des cylindres d'expansion pendant tout la course et avec une détente qui lui est propre*, puisque l'introduction est limitée à une fraction de la course. Avec la machine monocylindre, au contraire, la vapeur produite par la réévaporation pendant l'expansion, dans le cylindre, de l'eau de condensation, *ne se détand, mais agitsimplement comme si elle était fournée, a pleine admission par une chaudiere distincte*, a la pression correspondant; on perd ainsi un notable quantité de calories." The italics are Mons. Demoulin's. We believe that we were the first to place this fact before English readers, though it was about the same time announced in the United States. In one word, the compound engine is more economical than the simple engine working with the same range of temperature $T-t$, because in the former the principle of expansion is more fully carried out.

LIQUID FUEL.

From "Nautical Magazine."

THERE are not wanting signs that, in the immediate future, "liquid fuel" will have established a position of importance, as one of the products by which steam can be easily and economically generated.

Shipowners should be among the first to welcome such a result, nor should they be slow to allow it a fair trial. So many are the advantages to be derived from its use, which we partially pointed out in our last article on the subject, that it scarcely can fail in most cases to give satisfaction. The entire absence of smoke is not one of the least advantages.

There are several patent arrangements in existence for burning "liquid fuel," among them that of Mr. Percy F. Tarbutt, which has been fitted to the late steamship Himalaya, now renamed the steamship Marahu, for which extraordinarily good results are claimed; also Admiral Selwyn's, which was some time ago tried experimentally by the dockyard authorities, but, so far as we can learn, not with the most satisfactory results, although at the present time, at Middle Scotland Yard, London, on a piece of waste ground, the Admiral has had a marine boiler fitted up to burn "liquid fuel" by his arrangement, which all interested can see for themselves; and Colonel Sadler's patent burner, which has proved in the short time it has been in use to be more than a mere experimental success. This last-mentioned method of burning "fluid fuel" is already, and has been for months, in daily use for generating steam at a number of manufactories and shipyards, and among the firms who have adopted it are Messrs. Orr-Ewing's, the large firm of dyers at Alexandra, in Dumbartonshire; the Gartsherrie Ironworks (where it is also used for smelting iron); Messrs. Raylton, Dixon & Co.'s shipbuilders, Middlesborough; the North of Ireland Chemical Company, and also at Messrs. Sadler &

Co.'s Chemical Works, at Ulverston, Portsmouth, Stockton-on-Tees, and Carlton. At the various chemical works mentioned, creosote oil, a waste product of the distillation of tar, is used as fuel for the furnaces of the retorts used in distilling tar. The production of this oil is not confined to one firm; and in addition to the Chemical Company in Ireland we know that the Walkinshaw Oil Company at Paisley produce "liquid fuel," and are supplying it to manufacturers and others at 20s. to 25s. per ton, according to the place of delivery, and they likewise use this fuel for their own purposes.

There may be in the minds of some, doubts as to the possibility of arriving at such a saving in the weight of the fuel necessary to be carried by a steamer as 50 per cent., but when all the circumstances of the case are considered, it will be seen that this is a fairly reasonable result to be anticipated by the use of "liquid fuel" of an approved character.

Although "creosote oil" has not, so far as we can learn, been subjected to experiments for the purpose of ascertaining the exact component parts of the heating agents, yet it is believed that they are substantially the same as good petroleum, and, from the analysis of eminent chemists, we find that various solid and fluid fuels give the following percentages by weight of heating agents:

	C	H	O	CO	CH_4	C_2H_4
Anthracite coal.....	87.7	3.3	3.2			
Bituminous...	80.8	5.0	8.2			
Petroleum ...	84.4	13.1	1.5			
Coal gas.....		6.5		14.3	52.4	14.8
Generator gas.		1.98		35.5	1.46	
Water gas....		6.3	0.6	87.8	1.2	

By Dulong's formula—

$$H = 14{,}500\,C + 62{,}000\,(H - \tfrac{O}{8}),$$

we obtain for the combustion of one pound of

	Units of heat.
Anthracite...	14,500
Bituminous.....	14,200
Petroleum.....	20,300
Coal gas.....	20,200
Generator gas.....	3,100
Water gas.....	8,500

According to another authority

	Units of heat.
A pound of coal gives.....	14,000
" petroleum, light oil, gives.	22,628
" " heavy, gives...	19,440
" " refined, gives..	19,260
" Pennsylvanian, crude, heavy, gives.....	19,210

From these results we readily find the comparative evaporative power, which is as follows:

	Pounds of water evaporated from 212° Fahr.
Coal varying from.....	14.5 to 15.02
Petroleum "	19.95 to 23.44
Coal gas "	20.87
Generator gas "	3.11
Water gas "	8.7

and from what has already been stated, it may be fairly assumed that 1 lb. of creosote oil would have theoretically the power to evaporate 21.5 lbs. of water.

Experimental results with solid and liquid fuels show that there is, however, a wide difference in their efficiency, coal being for instance variously estimated to have from forty to sixty per cent., while it is generally admitted "liquid fuel" gives ninety per cent of efficiency. This great difference is largely due to the fact that the more efficient fuels require for combustion very little air, while for coal fully twice the theoretical quantity must be admitted to the furnaces to dilute the products of combustion; there are also great losses by stoking, in opening the firedoors to apply green fuel, damping down, &c. Basing our results on the percentages of efficiency just stated, and confining ourselves to the two most important liquid fuels, we find the

Actual evaporation from 212° Fahr. per pound of fuel in—

	lbs.	lbs.
Coal varies from.....	5.8	to 9.0
Petroleum "	17.96	to 21.1
and Creosote oil, say.....		19.4

which shows a possible saving in weight with using creosote oil in the place of coal of from 53½ per cent. to 70 per cent.

Now, in actual practice it has been found that, with land boilers of the Lancashire type, one pound of creosote oil gives as efficient results as 2.33 pounds of coal, which is equal to a saving of 57.08 per cent. This result was obtained at Messrs. Sadler & Co.'s works, Middlebro'; but almost the same has been obtained by Messrs. Backhouse & Dixon,

shipbuilders, who, despite the fact they bought their coals at 7s. 6d. a ton, find that liquid fuel at 25s. per ton is somewhat cheaper, owing to the saving of labor, in moving the coal, firing and cleaning furnaces, and removing ashes. We have recently had an opportunity of seeing a 30-ft. Lancashire boiler fired with "creosote oil," and it gave an exceedingly bright flame, and practically emitted no smoke, so as to lead to the conclusion that it might even be used with advantage, at least in some cases, for illuminating purposes.

In our last article we mentioned that the steamship Cobden had been fitted with Colonel Sadler's patent burner, but this is not the first vessel that has made a trial of this mode of burning "creosote oil." Some time ago the steamship Emmanuel had the furnaces of her boilers temporarily adapted for the consumption of liquid fuel, but as it was only an experiment, as in the steamship Himalaya, provision was left for replacing the fire-bars usually in the furnaces. Loose bricks were merely laid in the bottom of the furnace, and even with this rough and ready adaptation of the boiler, the liquid fuel gave every satisfaction on a voyage to the Mediterranean and back to the United Kingdom. In the steamship Cobden the arrangement of the furnaces is of a permanent character, no provision being made for using coal in the furnaces of the boiler that has been adapted for liquid fuel. The steamship Cobden's boilers are about 12 ft. in diameter, and about 10 ft. long, and owing to their comparative shortness it has been considered necessary to extend the furnaces about three feet beyond the front of the boiler. Inside the furnace there is a ring of brickwork of varying thickness about six feet long, and at the end there is a baffle or screen, with perforations of about three inches square. The doors of the furnace are in two halves to admit of the introduction of the burner and piping in connection with it. A small steam-pipe is led to the burner, and on lighting the fire the steam is first turned on, and then the oil which is led from tanks (as we will describe further on) is allowed to flow down a funnel into the burner, where it mingles with the steam. Then a lighted torch is applied to the outlet of the burner, which, by the way, is on a similar principle to Giffard's injector, and the only close attention required is at the lighting of the fire, as until the brickwork has become heated, a torch must be kept at the mouth of the burner. This is, however, only the work of a few minutes, for if a boiler were fitted with means of circulating the water, steam could be raised in about twenty minutes.

The tanks for storing the oil are, in the case of the steamship Cobden, placed under the hurricane deck and on the main deck, abaft the stokehole grating. These tanks are connected together with piping, which is led down to a small indicating tank in the stoke-hole. A gauge on this tank shows whether there is oil sufficient immediately available for the furnaces, if not, a cock is turned on deck, which permits of a further supply descending to the stoke-hole. Creosote oil being liable to crystallize at a temperature below 120° Fahrenheit, it is necessary to adopt precautionary methods for removing any crystals, grit, or other deposit to prevent the pipes choking. When the oil is being filled into the tanks on deck, it is passed through a sieve, and a further precaution is taken in the stoke-hole tank by having a strum box fitted in it, through which the supply from the deck tanks has to pass. The engineer of the steamship Cobden speaks very favorably of the whole arrangement, and stated that there was such an absence of smoke as to render a funnel almost a superfluity. The boiler has recently had a damper fitted to further check the great draught arising from the action of the jet of steam, and with one furnace only burning, it is kept in reality shut. Although a slight deposit of carbon is in the course of time deposited on the burner, during the seven voyages this vessel has made since the burners were fitted, not one has choked, and what little carbon has been deposited has been as readily removed.

The results obtained by burning creosote oil in the furnaces of the steamship Cobden's boiler have scarcely been so satisfactory from an economical point of view as in the case of boilers on land, but this is largely due to the fact that about half of the length of the furnaces project outside the boiler, resulting in considerable loss of heat by radiation. In longer boilers, where it would be practicable to

have the furnace entirely inside the boiler, without doubt the result would be a saving of fuel of at least 50 per cent. Boilers specially constructed with a view to burning liquid fuel, should naturally be expected to give better results than old boilers adapted, and as experience in using oil fuels increases, even greater efficiency may be fairly anticipated.

At present, there is being fitted up with tanks for the oil trade between the Black Sea and Antwerp, the steamer Fergusons, which vessel has been chartered for a lengthy period for the purpose of carrying oil. The furnaces of the boilers are being fitted with Colonel Sadler's patent burner, but in this case it is at present only intended to use "oil fuel" as an auxiliary to coal—only the leakages from the cargo being used—although it is very probable that after a time arrangements will be made to burn liquid fuel entirely in the place of coal. The alterations to this steamer are being carried out by Messrs. Westgarth, English & Co., engineers, Middlesbro', while the fitting of arrangements for burning the "oil" in the steamship Cobden were entrusted to the well-known firm of engineers, Messrs. Blair & Co. (Limited), at Stockton-on-Tees.

On the Clyde, as has already been noticed, progress is being made in the use of oil fuel for generating steam in boilers, etc., among manufacturers and others, and recently the steamship Fern, a passenger steamer belonging to the Laird line, trading between Glasgow and Ireland, has had fitted to the boiler furnace, arrangements for burning "liquid fuel," and the results of several trials have displayed many of the advantages to be obtained by its use. It is also stated that the Walkinshaw Oil Company have asked the Clyde Trust to place at their disposal one of their "Clutha" ferry steamers, for the purpose of further showing the practicability and special suitability of oil fuel to passenger steamers. We are, however, persuaded that the full advantage of adopting fluid fuel will never be obtained until steamers going on long voyages, such as to Australia and China, are allowed to give it a trial. Especially for steamers who remain away from the United Kingdom for a year or two, trading in the East, should this fuel be found to be economical; as hundreds of tons of oil could be taken from the United Kingdom in their ballast tanks.

In America, in our last article, we remarked that liquid fuel as yet does not appear to have secured for itself "a permanent position as an economical fuel." Although petroleum is relatively cheap, yet for land purposes there are wanting some of the advantages obtained by its use for steam vessels, and coal is to be obtained in most districts of America at a reasonable rate, while petroleum, in some districts, reaches a price of about £5 per ton. Recently there has been a revival in the use of petroleum, but in this instance as fuel for the boilers of steamers. Owing to the large deposits of petroleum discovered on the Pacific Coast, the price there for oil fuel is less than £2 per ton, while coal is about £1 10s. Evidently here is an instance where economy at once demands the adoption of the more modern product, and the Central Pacific Railway Company have not been slow to take advantage of the more economical fuel. All their steam vessels at Oaklands, their western terminus, are now burning petroleum or its waste products; and in the case of one of their vessels, which has been longest adapted to burn oil fuel, in five months of this year it was found there was a saving of fifty-six per cent. for fuel, as compared with the corresponding five months of last year when coal was burned.

Some hardware manufacturers in Birmingham, England, are taking pains to make themselves familiar with the goods of continental manufacturers which come into competition with their own productions. Such a course is worthy of wide imitation, and is the surest road to successful combating of the threatened difficulty without recourse to restrictive tariffs. That in many branches we are behind our continental competitors in the adoption of machine production, which accounts for much of the continental cheapness, is undeniable; nor does it follow of necessity that the continentals are making a profit upon all the trade which they are seeking to do with this country. Trustworthy evidence upon this point is much needed.

TIMBER.

From "The Building News."

MR. THOMAS BLASHILL, F. R. I. B. A., who took as his subject "Timber: Its Growth, Seasoning and Preparation for Use," said: Plants recognized as trees belong to two different classes—the endogenous specimens, in which the fresh matter is added in the center, and the exogenous trees, in which the increase was by coats of wood added on the outside of the stem. In the former class, of which palms were the best recognized illustrations, the center of the tree consists of but pith, with an outer husk of bark. In the latter class, to which all our timber trees belong, we easily recognize three distinct parts—the bark, the wood, and the pith. Now, consider the growth of one of the latter class of trees as it appeared, say, half a century after it sprouted from a seed. The pith, at first a very distinct rod of white, spongy substance, afterwards dried and shrunk, becoming partially dead. Outside was the wood in fifty rings, usually very easy to count. All, except a few of the outer rings, were comparatively hard and dry, of darker color than the rest, and practically dead also, because they had ceased to take part in the life of the tree. This was the heart now. Outside it was one, perhaps three or four—perhaps two—rings of softer wood, full of sap, light in color, and, when carefully examined, considerably alive. Outside this sapwood was the bark: first the inner bark—white, moist, living, consisting of many thin layers or rays. Finally, there was the outer bark, consisting of a layer containing such coloring matter as the stem might have, and an outer layer resembling the central pith; this might be thin, as in the birch, or thick, as in the cork oak. The lecturer next proceeded to inquire into the manner of growth of a tree, with reference to the eventual effect of external and internal influences on the timber. Having alluded to the rise of the sap, the lecturer showed that this fed the thin layer between the inner bark and the last annular ring, so thickening it that, tightly as the bark enclosed the stem, it had to yield to the pressure. The bark consisted of reticulated fibers, which allowed of a certain amount of expansion, but the internal pressure also caused it to crack and peel in places in various ways according to the thickness of the tree. It should be remembered that the stem was never quite correct, as the rings were never of the same thickness all around. They were generally thickest on the sunny side of the tree. If all the branches and roots were on one side of the tree, as when it stood at the edge of a wood, all the rings were enormously thickened on that side. In the Museum at Kew there was a section of a fir tree which measured from pith to bark on one side 13 in., and on the other side 4 ft., each ring being, on an average, four times thicker on the one side than on the other. The rings differed from each other also in thickness. As the tree developed fresh branches, the rings tended to get thicker. In a good season they were thickest, in a bad season decidedly thinner, so that a growing tree was a self acting register of the weather, as far as regarded its suitability for vegetation. In fact, we might count the rings back for centuries, and gain some generalization of the average summer weather of each year. When the sapwood was a few years old—say, from three to four years in chestnut, seven years and upwards in oak—the sap ceased to flow in it, and it changed in a season to heartwood, but not quite uniformly. Two or three rings would often be turned to heartwood on the sunny side of the tree, while they remained full of sap on the opposite side. The heartwood became solid, and its pores were filled up with any gums or resins that the particular kind of tree produced. The heartwood underwent no further change until the tree grew old, when it was the first part of the wood to decay. The sapwood kept up a sort of growth within itself as long as it existed in that condition. Another very important feature in the wood of all timber trees was that they produced plates of woody fiber that in the young plant connected the bark

with the pith. These were known as "medullary plates." They were not visible to the naked eye, except in oak, beech, and some few other trees. They were very conspicuous in the end grain of oak. As the trunk increased in size, fresh medullary plates start up midway between the older ones, and are kept growing at the junction of the sapwood and bark, and extend both towards the center and outer surface. The plates were only a few inches in depth up and down, but between them fresh ones started out, so that they overlapped each other. When we see them in the end grain, showing as bright, fine lines, they were termed "medullary rays"; when seen sidewise in a split log, they were known as the "flower," or silver grain. Having exhibited specimens of oaks showing these plates, the lecturer referred to the beauty they imparted to this wood, and mentioned that the plates could not be traced in the Spanish chestnut, ash, or elm. The medullary plates were not only ornamental, but very serviceable in oak timber. They added to the strength of the wood across the grain, so that the pins of oak tennons would not draw out. They were harder than the rest of the wood. In an oak slab which had seen many years' rough wear, say the sill in the ticket window of a railway station, on which the booking clerk dashed down his change, the silver grain stood up in ridges above the wood of the annual rings. They resisted shrinkage, decay, and worms, which would only bore through them in order to get at the softer wood beyond. A few things showed how the wood grew by annual layers. Let them suppose that three branches were removed from a tree, one being taken off close to the trunk, the second cut off with a few inches of projection, and the third left long enough to produce twigs and leaves. The new wood would, in a few weeks, grow over the first, leaving a wound in the wood called a bandgall. The second would have become a dead stump, owing to the absence of leaves, and would next be enclosed by the new wood. The third would continue alive, because it had been able to develop leaves. Iron spikes driven into trees were often grown over. He exhibited a specimen of English walnut wood, lent him by Messrs. Broadwood, in which the head of a long iron, used to fasten wire fencing, had been covered over with 3 in. of new wood. For all uses of any importance, timber should be taken from the heartwood of a sound, well-grown tree. The grain should be close and firm, and should sound well when struck. The annual rings should be of even thickness and the grain straight. It should be free from large or dead knots, shakes and blemishes. The chief defects found in a log of timber, besides those already mentioned, were—(*a*) cupshakes, which were gaping openings, forming segments of circles between the annual rings; (*b*) starshakes, cracks that ran towards the center of the tree; and (*c*) heartshakes, that opened in the center of the tree and spread toward the bark. If a heartshake were straight across the butt, and ran up the log in a perfectly straight direction, it did no harm; but if it wound so as to get crosswise, by the time it got to the other end the log was spoilt for most purposes. This tendency of the trunks of trees to twist was very curious. Most trees were subject to it; the Spanish chestnut in our country, the worst in this respect, twisted so violently, that by the time the tree was sixty years old it was usually badly torn by shakes and began to decay at the heart. The lecturer did not think that this peculiarity in growth had been explained; but there were some very interesting facts in connection with the development of trees that seemed to bear on the question. However quietly a young tree might appear to grow, there was really a constant strain existing within it. The center of the stem was straining to elongate itself; the outer parts were holding it back. These forces, as a rule, balanced each other, so that they could only be discovered by experiment. It was easy to excite the fibers of a young plant in one place so that it would, of its own force, bend considerably out of the upright. Besides this, although a stem seemed to be growing regularly, there was a tendency to grow first on one side and then on another, so that a movement was set up such as was most strongly developed in the hop. When the stem of a large tree twisted without being affected by violent winds, it was evident that one of these forces connected with its growth had got the

better of the other forces, so that the balance was not perfectly preserved. On the other hand, a young tree that had grown crooked, sometimes altered its habits so as to make new wood in a straight and regular manner. When that was so, we found in the center of that log the crooked wood of the young tree, and the history of its gradual amendment very clearly recorded. Mr. Blashill continued: we next come to the questions of felling and preparation for use. The best ages at which trees can be felled are, for oak, 100 to 200 years; Scotch pine and Norway spruce, 70 to 100; larch, ash and elm, 50 to 100; poplar, 30 to 50. The best time of the year for felling is the winter, because the tree is then most free from sap. Some trees may be felled soon after midsummer, because the sap is very quiet at that time. Oak is generally felled in the early spring—the worst time possible—because the bark, which is very valuable, is best obtained when the tree is full of sap. It is better to strip the bark off as the tree stands in the spring, and to fell it in the following autumn, when the sap has dried out of it. Teak is barked three years before being felled. It shrinks less than any wood in ordinary use, but it is said that this method renders the wood of teak more brittle. We have seen that the trunk of a growing tree is composed of wood in very different conditions. The interior is hard, comparatively dry, perhaps having its pores filled with resin or gum. The outer rings of wood are softer as they come nearer the bark, fuller of sap, more actively alive. Seasoning is the gradual drying of the whole log, so that the shrinkage of the outer part shall not be so rapid as to cause it to split and tear open before the interior has had time to part with its moisture. If timber is to be seasoned without artificial help, it should be stored over a dry surface free from vegetation, well packed off the ground, with free access of air, but not exposed to much wind. When squared it should be stored under cover to give shelter from rain, sun, and wind. So treated, oak will require as many months as the side of the log measures in inches. Fir will take half this time. The timber should then be cut into plank or large scantlings, and be still further exposed to the air, being so stacked that it cannot warp or twist. When it is cut to the sizes for which it is required to be used, it is again stacked until it becomes fully seasoned. Finally, it should be brought into a dry, warm room or shop till it is fit for joiner's work. After it has been wrought it must stand in the shop for a few weeks, until it has assumed the average condition of dryness that is permanently maintained by wood in our moist climate. It may then be finished off. If a round or square piece of wood has to be made thoroughly dry, it is best to bore a hole through the heart, so that the air may get access to the interior, and make it keep pace in drying with the outside, so that the shrinkage will be really equal all through. The length of time that has to be occupied by this natural process of drying, with the consequent expense, has induced many inventors to propose the drying of timber by artificial means. The most ancient method is that of drying in the smoke, which would be the smoke of wood fires. Besides drying it more rapidly than could be done by the gentle warmth of a room, the bitter deposit from the smoke was supposed to protect wood from insects. There is an old patent (Langton's) by which the sap is extracted from the green timber in a vacuum cylinder under heat. The length of time occupied and the cost prevent its use. Other systems for the application of considerable heat with the condensation of the extracted moisture are subject to the grave defect of causing irregular shrinkage with splitting of the wood, and though the cracks thus made close again to a great extent, the mischief done to wood that is intended for many important uses is incurable. For the use of the carpenter it is unfortunate that baulk timber and deals now seldom get any seasoning beyond the time requisite to convey them from the forest to the building, and the very imperfect seasoning the baulks get during their stay in the docks. Such timber, if closed up from the air near to moist walls or new pugging, will quickly develop dry rot, even in the upper floors of a house. Deals should have a year or two of open-air seasoning, being stacked with spaces between them, and should afterwards be gradually dried as they are required for use in the joiner's shop. Dry wainscot

from Riga and Odessa are cut into thicknesses, and stacked for three, four, or five years, being placed on end, as the sap is supposed to run down more easily. Planks are stacked horizontally, with spaces between them. Such woods as mahogany, black walnut, ash, birch, and maple, are treated similarly for a shorter time. In all cases the ends of timber require protection from sun and wind, as they dry more rapidly than the other parts. One of the old methods of seasoning is to keep timber in water for a fortnight after being felled. A good deal of the sap is thus dried out of it, and it becomes more durable, but is not so strong. Steeping it for a longer time injures it, particularly if it is kept floating only partly covered with water. Boiling and steaming timber have long been tried, and the processes have been almost or quite abandoned. The effect will be to wash out the sap, as in steeping. A fresh plan of steaming has lately been introduced, and is said by some who have tried it to be efficient, as for many purposes it may very well be. There are many purposes for which the strength of wood is of less consequence dryness, or at least permanence of the same degree of dryness. The sap has been extracted by the air-pump, which must promote dryness; but this plan does not seem to have been much practised. The ordinary means of drying artificially are various methods of keeping up heat in a drying-room, generally by the use of waste steam from machinery. When wood has been cut up into small scantlings the drying can be hastened in this way; but the further the heat is raised beyond that of an ordinary room the greater is the risk of irregular drying and over-drying. There is a new process for seasoning boards by means of dry, cold air. The air is passed through a furnace, so as to make it dry; it is next cooled, and then made to circulate through the piles of wood, so that in a few hours the boards are dry. One or other of these processes will probably be found so far satisfactory as to be useful for a great variety of purposes. There are no purposes for which wood is used in which the question of seasoning is of more importance than the higher class of cabinet work and the making of musical instruments. The best makers of such articles are exceedingly shy of artificial seasoning. In organ-building, such woods as mahogany, black walnut, birch, red, yellow and white deal, and a large proportion of pine, are used. These are stacked under cover, being carefully packed so that the air has free access through each stack. Hard woods require from two to four years; soft woods from one to two years of this seasoning after being cut to sizes. Even the workshop must not be too warm. The best pianos are made of wood that has been stored, first (as regards the deals) in open stacks protected from sun and the penetration of rain, and finally in rooms, where all kinds of wood, cut to sizes, are subject to the very gentle warmth of 70°. The common sense of this question of seasoning is sufficiently obvious. Wood must not be dried so quickly that it will be made unsound by cracks. It must not be dried so much that it will absorb fresh moisture and swell when it comes into the atmosphere in which it has to permanently remain. It is not merely a question of time, but of judgment, the objects being to see that the timber is gradually reduced in scantling as it dries, and so treated in temperature and stacking that it neither splits nor gets out of shape. There is very great diversity in the details of different experiments on the loss of weight by seasoning. Oak appears to lose from something less than one-fifth to more than one-fourth of its weight. Other woods vary still more. Teak and pitch-pine lose very little. Woods that come from remote places get seasoned, in a great measure, before they reach this country. Paints or other appliances that would close up the pores must on no account be put on wood that is not sufficiently seasoned. When dry, they may be serviceable by preventing the absorption of moisture. If the wood is full of sap, decay will take place much quicker when painted than if it were left uncovered. One of the most important questions, as regards the soft wood especially, is the prevention of decay. When in use in a building, timber generally decays either by rotting, through becoming sodden with wet, or by what is called "dry rot," which is caused by slight moisture, warmth, and want of ventilation. For the prevention of decay, the kyanizing process, which consists of the applica-

tion of corrosive sublimate by soaking, is effectual. The process of Sir William Burnett is still carried on by the firm established by him at Millwall. It does not seem that very much is required in order to make our resinous woods durable when exposed to the atmosphere. Complete exposure to the air, combined with the dryness of the ordinary atmosphere, is in itself a great preservative. Beech timber is useless in construction, as a building in which it is employed will be destroyed, chiefly through the attacks of insects, in a few years; but beech will last many years as a weather-boarding for such a building. In the Indies, such insects as the white ant destroy all woods that are not bitter, especially soft woods. When furniture is sent from England it may be partially protected by a coating of red lead; but if the insects get into the substance, they honeycomb it before anyone suspects that they are there. It is, therefore, advisable to impregnate the wood with some protective solution, by means of such machinery as has been mentioned. The essential oils, such as turpentine, have been recommended, but they are inflammable. Corrosive sublimate, arsenic, and other poisonous solutions of that class, seem most suitable. Creosoting is effectual, both as against decay and against insects, but it spoils timber for all of the best and finest purposes. The protection of wood from fire is a most important question, particularly as recent experience seems to show that we cannot depend on iron or stone. A heavy wooden beam will resist fire longer than any other beam or girder. The same with staircases. Such liquids as tungstate of soda could be forced into the substance of all wood used where fire is to be guarded against. Outward applications seem to be effectual in experiments tried on a small scale. To sum up the whole class of questions connected with seasoning, we want timber that will not shrink after it is brought into use, that will not warp or twist out of shape, will not decay through damp, and will not be destroyed by insects. Wood may also be indurated, that being the result of polishing and of varnishing to some extent. Upon the whole, it is desirable to encourage all means of treating wood, so that it may possess some of the advantages that are commonly attributed to iron and stone. In cutting up timber for use, the question of its grain as developed by the annual rings is of very great importance. The shrinkage being greater in the newer layers of wood, it must be cut so that this irregular shrinkage may be of no disadvantage in use. A plank taken out of the middle of a log will shrink at its sides more than in the middle; the boards that are cut out to right and left of this plank will curl outwards from the center of the log. If a log is cut into four quarters, the part of each quarter that is furthest from the center will shrink the most. Nothing requires such care in converting as oak timber, in which the medullary rays have so much influence. In order to show the beauty of the grain, as well as to provide wainscot boards that will be true in shape, it is necessary to get the boards as far as possible to radiate from the center to the outside of the log. If this is done, the medullary rays are cut through in many places, so as to show the silver grain. One method for doing this perfectly is shown in books, though I never heard of its being done in practice, the great expense and waste in sawing being an effectual obstacle. I have always had English oak "quartered," and then the boards have been sawn from alternate sides of each quarter—a method which insures at least eight perfect boards, and at least twice as many very good ones in regard to beauty of grain. Wainscot oak from Riga and Odessa comes to this country with two slabs taken off the opposite sides, and a cut clean through the center, or else it has the slabs taken off and a plank taken out of the middle. When it is partly seasoned, the plank has the center part taken out, as the part around the pith is likely to be unsound. Then each of the side logs is cut up into boards, several of which will go pretty nearly along the line of the medullary rays, and show the silver grain. Oak timber, as it was used in the beautiful Gothic timber roofs of the Middle Ages, and as it is still used in important parts of wooden ships, requires to be, not straight but bent. This bent timber is known as "compass" timber when it is 5 in. and upwards out of the straight in a length of 12 ft., and is more valued on

that account. Ash timber does not appear to have any sapwood, all the wood being of the same color, and there are foreign timbers with the same peculiarity. It appears, however, that the worm finds out the part that is sapwood, so that it has the usual defect. In elm timber the sap is reckoned as good as the heart. The timber does not improve by seasoning, but should be used green, and even kept wet until wanted for use. When used in flooring, I have known the oldest elm boards shrink considerably if they were merely taken up and planed. We must not overlook the important uses of the finer kinds of wood when cut up as veneer. The fact that veneer is very much abused is no argument against its legitimate use. It should only be used in panels, so that the framing will be of solid wood of good, plain colors, to set off the beauty of the panels. The most beautiful veneers are still cut with the saw, about ten to sixteen to the inch, though knife-cut veneers are very largely used. By steaming large logs of timber and putting them in a lathe, the knife will pare off a continuous sheet from the thirtieth to the one hundredth part of an inch. The chief woods used are rosewood, zebrawood, satinwood, tulipwood, mottled mahogany, walnut burrs, bird's-eye maple, birch, Hungarian ash, and sycamore, and there is a great variety of beautiful Colonial and American woods, producing every variety of color.

A RATIONAL POLICY OF PUBLIC WORKS.

By L. E. COOLEY, President Civil Engineers' Committee on National Public Works.

Journal of the Association of Engineering Societies.

[The theory of the argument is, that the utility of a system of public works must be apparent, in order to furnish a sound reason for providing a special service, or a change in the present service, for its conduct. In giving prominence to interior improvements, it is assumed that there is no difference of opinion as to the great importance of coast works.]

INTRODUCTION.

Is there need of better provision for a system of internal improvements?

If so, what action should be advised for determining a rational policy and providing a service for carrying it out?

To base the consideration of this question solely on the public weal, is to promote the highest justice to all interests.

If the utility of a system of internal improvements be admitted, the importance of a specially organized service is self-evident. If Congress is prepared to adopt a consistent and uniform policy toward public works, it is ready to provide an adequate service for their charge. That the time has come for the definite inauguration of such a policy may not be sufficiently clear to gain the general consent of our legislators. Meantime, local interests which can influence votes will dictate appropriations, and perhaps secure special commissions and appointees thereon. Congress, as hitherto with all irregular appropriations, will continue to assign their expenditure to some one of the great departments which may be provided with a bureau more or less well adapted for their disbursement.

To promote a change to a rational policy from the present wasteful and unfruitful system, if indeed it may be called a system, is the duty of a profession which can most clearly understand its deficiencies.

Any intermediate steps that might be taken would seem to afford greater possibilities for evil than the condition it is sought to remedy. To see any necessity for change is to recognize the whole truth; to urge its full conclusion is likely soonest to attain a desirable consummation, free from the suspicion of personal or class interests. Accepting these premises for the time being, the reasons for a policy different from that now prevailing are in order.

THE UTILITY OF A PUBLIC WORKS SYSTEM.

Competition by Water.—Lake craft from Chicago or Milwaukee to Buffalo or

Erie, receive from one-third to one-fourth the through rate by lake and rail to the sea-board*; or the lake rate per ton-mile is one-fourth to one-sixth the rail rate. If these rates may be assumed to represent relative cost of transportation, then it is simply a question of how far the size of boats may be reduced, how much their speed shall be lessened, or what difficulties of navigation are to be contended with, to bring the cost of water carriage up to that of rail. The margin is certainly ample to admit great possibilities in a well-considered waterway system.†

Commissioner Fink, of the Trunk Line pool, has stated that the Erie Canal influences rail rates to the seaboard as far west as St. Louis and south to the Ohio River. The Illinois and Michigan Canal, of less adequate proportions and with limited commerce, favors all the towns along its route with a rail rate much less than that of towns distant a day's journey by wagon.‡

The lines of boats on the upper Mississippi give great advantage in north and south rail rates to the cities along its course, and even the occasional boat which once or twice in a season may reach a Missouri river town, mitigates the railway tariff. The few months of intermittent navigation on the Ohio are profitably utilized by coal fleets, heavy products and even merchandise, and the lower Mississippi exercises an influence quite out of proportion to southward-bound commerce.§

Our waterways, undeveloped and unimproved and of inadequate capacity, in fragmentary systems and closed for a part of each year, frequently not in the direction of traffic requirements, afford their bordering towns cheaper rates and indirectly benefit the whole country.* It was repeatedly admitted by railway officials before the Interstate Commerce Committee of the U. S. Senate, the past summer, that the water route, though it may not carry a pound of freight, exercises a *moral* influence over rail rates. A channel that can be navigated is a latent force which becomes active when rates are pushed above a certain minimum.† If this be now true, what benefits may not be anticipated from the development of an adequate system, fully navigable at all times in the South, and, when not closed by ice, in the North?

France has, perhaps, a more fully developed waterway system than any other country, having expended $218,000,000 on 7,069 miles of interior or non-maritime lines.‡ Within the past few years she has been improving rivers of a class, at present, quite unworthy of attention here. Although rigidly controlling her railways, of which she becomes the owner after a limited time, she has recently given renewed attention to her waterways with a view to their fullest development in accordance with the latest studies; $270,000,000 have been set aside for the purpose by her Government and her municipalities, and this for a territory considerably less than the combined area of Illinois, Iowa, Wisconsin and Minnesota. Under the circumstance of full control and ultimate ownership of all highways of commerce, this may be taken as the unbiased judgment of her statesmen and engineers. How puny seems the river and harbor bill for a country like the United States!

Manchester, England, has recently concluded to bring the sea to her doors

* Statement by S. S. Merrill, manager of a line of lake boats, before the U. S. Senate Committee on Interstate Commerce, at the Chicago session, the past summer. The lake route is practically twice the rail distance by five different lines from Erie or Buffalo to the seaboard. Lake rates on coal from lower ports, less than one-third that to the Mississippi, for five times the distance.

† Previous to 1838, but 9½ feet could be carried through Lake St. Clair; 12 or 13 feet up to 1874, and 16 feet since. Present plans contemplate an ultimate depth of 20 feet for lake navigation. The great reduction in lake rates following increased draft and improvements in vessels and machinery, may be expected to continue beyond all hope of rail competition, when enormous capital accounts and fixed charges are considered.

‡ The railway commissioners' rate on wheat, generally adhered to at non-competitive points, is 7.2 cents per bushel for 130 miles. The rail rate from Henry to Chicago, 130 miles, is the same as canal rate, namely, 3 cents per bushel.

§ The influence of the Mississippi river on rates to Atlantic ports, especially from St. Louis, is discussed in the reports on Internal Commerce of the United States, by Joseph Nimmo, Jr., Chief of the Bureau of Statistics, Treasury Department. See Report for 1880, *et seq.* Also papers by Fink and other authorities.

* The far-reaching effect of competition is shown by Commissioner Vining of the Western Trunk Line Association. See *Railway Review*, Oct. 18, 1884: "Necessity for a Classification of Freight."

† "They can only increase their charges over the charges made by water routes to the extent that they offer additional advantages; while somewhat higher rates can be charged by the railroads, the basis of their charges are the charges made by water-lines."—Albert Fink, Sept. 17, 1873, before the U. S. Senate Committee on Labor and Education. Virtually the Chicago and St. Louis rates by water are the basis to which the rail rates of the country are adjusted.

‡ New lines authorized, 1,813 miles.

through a canal thirty-five miles long, to cost $40,000,000. The maximum rates are fixed at one-half the present rates by rail or canal from Liverpool.*

It would be a work of supererogation to cite further proof that water carriage in proper channels is the cheapest method of transportation. Was it not Lord Dundreary who noticed that all the great rivers ran by the big cities?

The Future System.—It requires but a superficial examination of our country to appreciate its possibilities in a magnificent public works system. Fringed about by a deeply indented coast, harbors in profusion invite fuller development. Great lakes and rivers, extending remotely from market points, drain basins unexampled in mineral and agricultural resources. Natural channels, susceptible of improvement to ample capacity, are well distributed. Topographical features favor the linking of the river systems to each other, to the lakes and to the seaboard.

The canal systems of our fathers are of the past, and the day of meagre channels and small boats is drawing to a close. The railway is better adapted to the quick, detailed and distributive traffic of our country. Natural channel-ways, developed to a capacity suited to fleets and boats of large burden, so articulated at vantage points as to require no change of cargo—a great trunk system with tributary water-ways of indefinite extent, joining market points of heavy traffic origin and destination—this is the system of the future.†

It has been stated that the Mississippi Valley, comprising about one-third the territory of the United States, contains 15,000 miles of navigable streams; *i. e.*, streams which have been navigated and legally known as navigable. The question was investigated in 1881.* Taking the main river to Cairo and the basins of the Ohio, the upper Mississippi and the Missouri, 10,000 miles of rivers were found, the projects for which considered an improvement feasible, at reasonable cost, for boats of a large class. This estimate omitted the tributaries of the lower river and a great number of minor streams for which appropriations have been made. On the same basis the natural channels of the balance of our territory would readily raise the estimate to 20,000 miles. To make the system as complete as in France, by embracing minor streams and more extensive improvements, would give a mileage of not less than 50,000. To-day, 10,000 miles of improved channels would constitute a primary trunk system, about one-twelfth of the railway mileage, which would directly or indirectly regulate traffic charges throughout the country. Increasing density of population, traffic grown heavier and more concentrated, and the margin of profit on industry growing smaller, would gradually demand extensions of the system until developed to its limit of usefulness.

Waterways, as at present existing, in detached lengths, unsuited to economical transport, unavailable a good portion of each year, cannot be expected to attain great results, and yet their influence is admitted. Waterways should constitute connected systems as well as railways, and they should be so planned as to avoid transhipment as much as possible, the same capacity cannot everywhere be provided, but improvements can be based on a few well considered types, uniform throughout the country, in lieu of present methods by detached works without reference to other works with which they will some time constitute a system.

What can be afforded.—Our territory extends so widely as to make the traffic tax between the producer and the consumer, the agriculturalist and the manufacturer, the interior and the seaboard, a heavy burden. The amount by which this burden can be lightened is the measure of what can be afforded for internal improvements.

* Depth, 26 feet; lockage, 60½ feet; locks, 550 feet by 60 feet.

† Of what use are rivers? "To feed navigable canals," said James Brindley, the father of English canal engineering, more than a century ago. This remark, in a measure true at the time, became the chief dogma of canal engineers. The practice of this branch of the profession soon became fixed, and has shown little elasticity or advance under the changing requirements of the age, or the revolution wrought by the introduction of steam. Even as late as 1848, the Illinois & Michigan Canal, with meagre prism, was completed for horse boats alongside a river unusually well adapted to slack-water improvement for steamboats of a large class. The locks and dams on the lower Illinois is another case of reversion. Had dogma given way to wise forethought, the same expenditure could have resulted in a magnificent navigable channel from the Lakes to the Mississippi, and made of the Upper Illinois the Merrimac of the West.

* "Proceedings of the Missouri River Improvement Convention" (p. 59), St. Joseph, Mo., 1881; also, "A Plea for the Missouri River Improvement," by L. E. Cooley and S. H. Yonge, published by the City of Leavenworth, Kansas, 1884.

The National Government, from 1790 to 1879, expended on all our rivers and harbors, $81,747,604.45.*

The State of New York. up to 1873, had expended on her canal system an equal amount, or $81,577,993; and received therefrom in tolls, up to 1876, $128,067,030; while the surplus earnings on the Erie Canal alone, up to 1873, above cost, operating expenses and maintenance, were $40,175,594.† The indirect benefits to New York and to the whole country have been immeasurable.

At the end of 1884 the railways of the United States aggregated 125.150 miles, with a share capital and indebtedness of $7,676,399,054, or $61,400 per mile, and on this sum it endeavored to collect dividends. Although the year 1884 was one of unusual depression, the gross earnings amounted to $770,684.908, and the net earnings to $268,106,258, or $2,142.28 per mile. The average rate was 1.236 cents per ton-mile.

It is not proposed to argue any abstruse questions in political economy. It is evident that if a system of public works could have saved to the people 10 per cent. of the gross earnings in 1884, and this ratio of saving could be maintained by its construction, an expenditure of over $2,500,000,000 at 3 per cent. could be afforded for its development. If far better results are to be realized, then by that much would the general public benefit in a clear gain. The railways would still retain traffic ample for a reasonable return on their *fair cost*, for all lines judiciously located and properly constructed. In the greater prosperity that would ensue, an increase in that traffic for which the railway is best adapted would doubtless provide better returns. While it might not be expected that waterways would promote the construction of railways and enhance their value, such has been the result throughout the Mississippi Valley, and from the great lakes eastward.

It is impossible to infer to what degree of perfection $2,500,000,000 could bring a public works system. This much is certain, however, that Congress cannot expect to attain great results with the expenditures of 90 years, an amount less than the aid to the Pacific railways in their brief history.‡ A well-defined policy, a full studied scheme and annual appropriation reasonable in view of the purposes to be subserved, would gradually bring relief in reduced cost of transportation.

The value of navigable channels is gradually impressing itself on the people. Along lines of heavy traffic their cheapness is admitted. As a bulwark against extortionate rates even before demanded by traffic, they secure recognition. Every steamboat and ship owner is a free competitor for traffic, thus adjusting profits to those of general business. A traffic charge is a tax which it is the function of Government to lighten as much as may be possible.

If the claims for an interior system do not receive full assent, our coast and lake harbors of themselves can demand better provision. The increased draught of lake and ocean vessels makes deep entrances to harbors imperative. Every port on our 20,000 miles of coast line requires the watchful care and skill of the best service that can be provided. Many of these ports are at the outlets of great arterial systems which may carry the products of a nation to the seaboard, on its way to domestic or foreign markets; and they are likewise the natural entrepots through which the products of other lands may reach the great interior.

Can the growing sentiment of our people for interior and coast improvements, which is constantly breaking out in popular conventions and crude enactments in our legislative chambers, be indefinitely ignored?

THE GROWTH OF PRESENT METHODS.

A National Policy.—The policy of the General Government for the first half century of its existence was foreign to the construction and improvement of waterways and harbors, although the

* Four bills have been passed since, aggregating $53,813,235; and $4,250,000 has been paid on the South Pass jetty improvement. A partial list of the work done on rivers and harbors, and such canals as have been turned over to the general Government, by States, corporations and private individuals, up to 1879, aggregates an expenditure of $31,021,423.32. In aid of such work, the Government has granted 3,057-840 acres of the public domain.

† Cost, including that of the original canal, extraordinary repairs and improvements up to 1876, $49,160-986.93. The free canal system went into effect at the beginning of 1883.

‡ The subsidy to the Pacific railways was $64,623,-572. The principle and accrued interest, June 30, 1884, was $102,934,794.08. About 150,000,000 acres of land have been granted and about 50,000,000 patented or earned. It is reported that 100,000,000 may be forfeited at the will of Congress.

construction of national roads was largely entered upon. Notwithstanding the efforts of several of the States, notably New York in 1811, to induce Congress to undertake public works or to give aid, congressional action was limited to an occasional land grant for state enterprises, a practice that only grew to full fruition in the building of the land grant railways by private corporations. Accepting the policy of the General Government, the several States largely entered upon the construction of canal systems and even the improvement of rivers and harbors.

In this early day the constitutionality of public works construction by the United States, except as warranted by military necessity, was gravely argued, and is even now brought forward in relation to special schemes. The military necessity plea served some earlier projects and again came to the front at the close of the civil war.

Under the commerce clause of the constitution, the Supreme Court has defined as navigable waters of the United States, those that "form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water." Although the earlier decisions run back fifty years, it is only since 1870* that the limits and powers of the General Government have been well defined, and even now there are many points undecided. The paramount jurisdiction of the General Government is assumed in recent river and harbor bills and bridge laws, and of late States have recognized their subordinate powers on domestic streams and in bridging navigable waters. The construction of artificial channels around obstructions has been for some years accepted as proper, and as links between natural systems they are obtaining similar recognition. In fact, it may be doubted if there is any limit to the powers of Congress to provide commercial highways in the interests of commerce.

The history of our waterways ascribes to them remarkable prosperity until the advent of the railway systems, and as pioneers in the first development of the country. During the speculative and constructive period, with the large profits and rapidly changing values incident to the inhabitation of new territory, the railway, even with heavy traffic charges, proved its adaptation, and the waterways gradually fell into disuse. With the development of market centers, furnishing a cargo or bulk traffic in place of the old coasting trade, with a settled and dense population and fixed industries, with lower margins of profits on which freight charges most seriously infringed, waterways have taken on new life, and their improvement is loudly called for. With the long-recognized importance of coast harbors, this call is co-extensive with our land.

The history of this question passes from a period when internal improvements were regarded as the peculiar function of the States, up through a marvelous development of transportation facilities by corporate capital, in which commerce has become a mighty problem of interstate concern, until a public works system is recognized as the province of the General Government. That the growth of this idea will in time find expression in proper legislation, no one can doubt. That it should, ere this, have resulted in a well-defined policy, is the belief of students of the subject.

Legislation.—Our public improvements have secured appropriations most largely through local and sectional influences. Great popular conventions are held to express to Congress the earnest desire of the people for improved waterways and harbors. In these conventions diverse interests often strive for expression, and even in Congress they not infrequently so antagonize each other as to defeat legislation of great public moment. The limits hitherto set for the river and harbor bill, the great number of projects demanding attention, and necessarily included, have resulted in the arbitrary scaling of estimates to a fraction of what is required in individual cases to prose-

* Sup. Ct. Decisions, 1870: "The Daniel Ball." The Grand River was declared to be a navigable stream and not a "domestic stream" solely under the jurisdiction of Michigan. The first important case was in regard to an exclusive franchise granted to R. R. Livingston and Robert Fulton for the navigation of the waters of the State of New York by boats moved by fire and steam. The doctrine was more fully defined in Gilman vs. Philadelphia and in the Wheeling bridge case, as also in the Rock Island bridge case.

cute work economically or to even achieve success.

That improvements should be local and diverse is to be expected. That there should be a medley of bridge laws, or none at all in some instances, is not strange. That even in connected or adjacent navigations, forming parts of a local system, there should be such diversity in permanent structures as to call for different classes of boats, is a legitimate result of present methods. That works should be undertaken which are totally separated from continuous navigable waters, or that expenditures should be made only remotely connected with the interests of navigation, need not be a matter of surprise. Do we wonder that the river and harbor bill should fall into disrepute, and the true friends of a public works policy pray that it may be killed annually until more rational methods can prevail?

The only effort which has been made to lay out a system of improvements was by the Windom Senate Committee of 1874. Although much interesting information was collected and some general recommendations of value made, no great result could be achieved by such a body, or by any body, in a brief space.

The study of internal improvements and their execution is the proper work of an organization constituted for that purpose. The local or sectional scheme should go directly to this department for examination, and reach our legislative halls only as a project in harmony with a general plan. Finally, in the elaboration of a general plan, we may suppose all local or sectional interests to have been properly consulted. By such methods, and appropriations commensurate with the purposes in view, will our public works assume a proper dignity.

Professional Organization.—With the growth of public improvements, the Military Engineer Corps is found in a neutral and powerless position. Originally, appropriations for works of military necessity, for roads or for explorations, were naturally delegated to the Secretary of War. That their disbursement should have been assigned to the Engineer Corps of the Army, even had other talent been then available, was proper, and the usage has continued to this time, although the purpose has largely changed. Except by custom and implication, Army engineers have no legal or legislative status for civil work, and may be considered as virtually on detached duty. Without proper status, they are powerless to devise or recommend a system. Even an opinion, in accordance with military ethics, may be impertinent, and wise enactments must take the chance of discovery by men unfamiliar with the requirements. Without tenure in the work to which Army engineers are assigned, they are assigned, they certainly cannot provide a status for their civil employés.

Such conditions not generally understood, have naturally resulted in dissatisfaction, and it is not strange that under the spur of special interests, a remedy should have been discovered in the commission panacea. The apparent advantage to one section through a commission leads to a struggle for like advantage elsewhere, until every large sectional interest may be expected to insist on its commission. This leads to a gradual disintegration of responsibility. Appointments become a matter of influence, with no assurance of training or skill for the work, and the tendency is inevitable to self-seeking and political control.

Although commissions, *per se*, may have been a benefit to our public works in mooted questions and special installations, yet, thereby, an organization has not been provided for their better conduct, nor has a desirable tendency been inaugurated. It has gone too far, however, to warrant no action or a return to the old regimen, and it should be wisely met by comprehensive legislation.

It is certain that any organization thus far constituted is quite unsuited to the requirements. Until, however, Congress defines a policy toward public works, a special organization can have little reason for existing.

THE DEFICIENCIES OF THE PRESENT ORGANIZATION.

To present without bias the deficiencies of the present river and harbor service is no light or enviable task. The organization of the Engineer Bureau is purely military, and solely as an arm of the military establishment is its policy defined. It has no proper legislative sanction for civil work, this being in the nature of a detached service by assignment of the

Secretary of War, originally to works of military necessity. Adequate training and experience are not demanded for important civil duties, and officers are transferred from time to time with too little regard for the interests in which they are enjoyed. It cannot well be otherwise where all duty must be subordinated to the military requirement. All laws, regulations and rulings are essentially military. How ill adapted they may be to the requirements of civil work, is chiefly known to those who have had experience under them. Regulations in regard to purchases, contracts, property; in regard to vouchers and reports of all kinds, are elaborately annoying, greatly increasing the cost of supervision, often tying the hands of the resident engineer, or even defeating success in work requiring dispatch. A set of regulations based on the field requirements of civil work would promote sound business methods, but this is clearly impracticable until the whole matter is formally delegated.

The Corps of Engineers, U. S. A., at present comprises 112 members; of these, 35 are engaged in strictly military duty, 51 in strictly civil duty, while the balance have both military and civil duties. If the assignments be followed up in detail, it is found that, with few exceptions, officers attain the rank of captain before assignment to civil work; in other words, that five or six years of post-graduate study and experience is regarded as essential to the completion of their military training.

For their civil work, no special course of study, preparation, experience or aptitude is made a pre-requisite; yet no capable engineer officer will say that his problems of civil engineering taxed him less, or were less difficult than those of his military experience.

The first civil assignment is usually as assistant to an officer of experience. As preparation for actual charge has not been made, the duties performed are generally nominal. Thanks, however, to an excellent training, experience in time may remedy deficiencies, though the lack of detail knowledge of field practice and construction may be sufficiently apparent.

Each district officer is directly responsible to the Chief of Engineers only, who, with divided duties, is supposed to consider and approve every project in the United States. The relief afforded by an occasional board is not a comprehensive one, and, practically, there is no inspection service. The corps boasts of many civil engineers of high attainment, and that any success should be reached under a lack of proper method, is gratifying evidence of what might result from a definitive policy.

"Military and civil methods of administration are entirely diverse, and proceed upon diametrically opposed theories. The military officer plans and commands; the civil officer hears, weighs and decides."* That ideas are sometimes outranked in boards of military engineers, is the evidence of junior members. In like manner, may the subordinate service fail of a true development.

It has been remarked that the man of engineering habits of thought is a poor field officer.† If so, how far is a military training adapted to making the best civil engineer? One thing is certain, that the student who has mastered his course in a good engineering school and had five or six years' experience as assistant under a competent chief and in commercial methods, has fuller qualifications than the officer, who comes to his work after his post-graduate military service, a novice except in ability to organize. This of itself is a full argument for more rational methods.

Perhaps the most serious defect of our Corps of Engineers as an organization for civil work lies in the fact that responsible position is attained by transfer from a service of little similarity, and without antecedent training and experience; while the great body of whom technical knowledge and skill are required, perhaps equally competent, certainly with special training and years of experience, are ineligible. This class of men, under the general title of civil assistants, outnumbers the officers from three to six times. Their employment is of course temporary, depending on the annual appropriation bill. However competent or ambitious to make this specialty a life work, they

* Major J. W. Powell, Director of the U. S. Geological Survey, before a joint committee of the two houses of Congress.

† Another phase is illustrated in a recent remark of Adj -General Drum, in regard to the value of an expeence in civil life, as evidenced by the great leaders which the late war brought to the front. He might also have cited the records of army and navy officers who have served in the Coast Survey.

are confronted by uncertain tenure of position and ineligibility for responsible charge. In fact, have we not the anomaly of a service, in which, as a general thing, the superior or responsible officers are unfamiliar with the field duties which they are called upon to direct and supervise? Does not this reverse the logic and the method of all human experience?

This condition cannot result in the best service. The time of the civil assistant on Government work does not average three years, or in other words, when some competence in a difficult specialty is attained at Government expense, it is immediately thrown away. The best talent of course, will not remain without hope of future reward, and ever in the face of the growing conviction that the special experience acquired can avail little in other pursuits. It is not strange, therefore, that a large proportion of our best technical graduates should enter a service to find out their mistake, and resign with more or less resentment toward a condition of affairs in which all concerned are alike powerless to remedy.

The deficiencies of the service grow out of legislative inadvertence and military point of view. It is no plea of justice to the civilian, that could, of itself, demand a change. There is but one question, and that is—what is most expedient, or what will secure the best result? All that can be insisted upon is, that the present plan, or rather no plan, for it has grown like Topsy, is most ill adapted, and that a well considered change is demanded in the interest of a better service. All familiar with the matter recognize this, and it remains to define its character.

SUGGESTIONS FOR A SPECIAL ORGANIZATION.

The wise man is ready to rebuild when he tears down. Unless a well digested system can be substituted, to argue a change is folly. The interests concerned are far too important for other than grave deliberation and conservative methods. If we have not faith that Congress, recognizing the advisability of change, will order wisely, then far better to have left our efforts undone, unless, indeed, they should ameliorate somewhat the inevitable.

A cursory study of our river systems, lakes and coasts, suggests the outline of an organization adapted to the requirements. The country naturally segregates into several grand divisions or departments within each of which there is such similarity in physical features, such community of interests, as to demand related works or plans in mutual harmony. These grand divisions subdivide into districts of less individuality, but integral members of the group which constitute the department. Adjacent departments will have much to consider in common, much to harmonize in the general development of trunk lines and the fixing of standard requirements for improvements of similar capacity.

Let the district be taken as the unit, with an officer in charge, and an organization competent for the multifarious duties involved in the design and execution of work. The several district officers may constitute a board, charged with the common interests and general plans for the department. Its chief should have no special charge, but should act as executive officer of the board. The several department chiefs may constitute a central board for the consideration of wider interests and the supervision and development of the public works system as a whole.

Within the district, resident engineers and assistants must be provided, down to the lowest grade requiring technical training, skill and ability. Starting with this grade, which may be one of probation, promotion should be step by step in accordance with a well-advised plan, preserving, however, elasticity enough to utilize the best thought in the profession. Such a system would not be unlike that of Prussia, in which all officials are educated and trained for their work as civil engineers.

Having decided upon a policy and the character of an organization, it is evident that to create it *de novo* and develop it to full efficiency, is a work of years. It is a truth that many engineers too little appreciate that river and harbor work is pre-eminently a specialty, requiring a high order of analytical ability, executive capacity and skill, to cope with active forces of destruction. The judgment acquired by special experience is not to be lightly thrown away.

As before stated, less than one-half the Engineer Corps is at present required

for military duty, although the prospective and necessary work on our sea-coast defenses may soon demand quite its entire services. So there is now available over one-half the Engineer Corps as the nucleus of a civil establishment; and, with such civil assistants as may have developed special fitness, a fair working organization could be provided at once. It would be a matter of three or four years only before the new organization had become a consolidated, well-adjusted, living force, utilizing all the available experience and gradually establishing itself on a civil basis.

The organizing ability possessed by many of our engineer officers would be of the greatest service in the earlier stages of the new establishment. With the law intelligently framed and its provisions carefully worked out, the execution could not be left to more willing or appreciative hands; and doubtless many of attainment in civil work would elect permanent appointments in the new service. The deficiencies of our present no-system are too well recognized by those concerned, not to make a wise remedy devoutly to be wished. Thinking men will not resist a change which insures better results, provided their vested interests are in some manner conserved.

WHAT SHOULD BE RECOMMENDED?

If the various phases of this subject have been clearly presented, then it is apparent that there has been a gradual change in attitude on the part of the United States toward internal improvements; that the time is approaching, if not already here, when the formal adoption of a well-considered policy will be necessary; that hitherto appropriations have been irregularly made, largely through the influence of local or sectional interests and without a general purpose; that their expenditure has been delegated, like all irregular appropriations, to one of the departments for disbursement; that this disbursement has been assigned to a military bureau, not organized for civil work, and having no legislative status therefor; that this has not, and cannot, for reasons not generally understood, be satisfactory; that various interests have inaugurated the idea of commissions which, however well adapted to particular purposes, tend to an undesirable end; and that action should be taken looking to a rational policy and the provision of a special organization for its execution.

The general character of an organization which would seem to be adapted to the requirements of our great territory has been outlined, and ideas advanced as to the best method of attaining its consummation. It has been shown how all projects may be presented in accordance with a well advised plan, thus doing away with the unseemly strife of section, locality and district, and how great results may be attained for the common weal through a system of public improvements. While it is our privilege and duty as citizens to discuss these matters, having reached our conclusions, it is incumbent upon us as professional men to point out the road to a solution.

It is evident that the consideration of this subject involves many complex questions. The work which is to be performed must be well understood. An organization which will secure the highest professional results and be in harmony with the genius of our institutions must be provided, and the legislation adapted to its needs well outlined. When the main requirements have been studied, experience abroad, so far as it may have a bearing, should be considered, and conclusions so matured as to eliminate purely individual opinion.

It is believed that the whole matter is in such shape as to make it impracticable to attain a definite system by a gradual change, or a species of growth. It will require time to bring those concerned to a full realization of the state of affairs and to an agreement as to a wise course to follow. To fly from the evils we have to those we know not of, can be ill afforded.

Therefore, it would seem wise of Congress to provide a board of Army and Civil Engineers, acquainted with this matter and realizing the necessity for a change, to consider the whole question of legislation and organization. Such a board could collate all the thought pertinent to the subject, and present its conclusions with recommendations for the consideration of Congress.

As engineers, we would feel confident that the subject would be handled as

wisely as could be provided for, and that, for a purely professional organization, Congress would give heed to the conclusions.

SUGGESTIONS FOR A "DEPARTMENT OF PUBLIC WORKS."

The executive departments of the government present a curious medley of bureaus designed for sundry and various useful and special purposes. Of the seven great departments, three, those of State, Justice and the Post-office, confine themselves strictly to their special work. The Navy Department indulges in occasional canal surveying. The War Department takes upon itself Meteorology, Geographical and Geodetic surveys and Internal Improvements. The Treasury has a Light-house establishment, a Coast and Geodetic survey, a Public Buildings bureau, a Marine Hospital service, a Bureau of Statistics, a Steamboat Inspection service, a Life Saving service, a Revenue Marine, etc. The Interior has a Fish Commission, Geological surveys, Patents, Land surveys, Pensions, Indian Affairs, Census, Pacific Railway Commission, Capitol Building, etc.

It is apparent that the majority of these assignments are utterly incongruous. They have frequently come about through the recommendation of cabinet officers, under the initiative of some ambitious and stirring subordinate. Some of these bureaus are misplaced or in the wrong department and could be transferred with good results, while other departments should be confined strictly to the work for which they were organized. Why the Treasury should concern itself with other matters than those of finance, or the Navy and War Departments indulge in work foreign to their purpose, is anomalous. The special bureaus cannot assimilate the general service of the departments. It is not easy to provide the special organization, rules and supervision, which may be required.* These bureaus become, in nature, petty, semi-independent satrapies.

That it would be wise to segregate all our technical bureaus, or those requiring scientific and constructive skill, from their present unrelated departments, and aggregate them in a department by themselves, cannot be seriously questioned. Harmony in organization, regulations well adapted to the work, proper supervision, and the interchange of special experience, would all be promoted. Such a department would have its various purely scientific bureaus, its bureau of surveys, of architecture, of internal improvements, etc., all based on such a thorough civil service as must result where technical attainment is uniformly required.

Some of the bureaus referred to have been the subject of agitation with a view to better or more rational methods. Sooner or later all these interests must center about the common idea of a department.

The adoption of a consistent policy towards our public works and the provision of an organization especially adapted to their requirements, is a purpose in which the engineers of our country can unite for the highest public good.

At the same time, the status of our profession may be promoted in greater degree than by the solution of any other problem of our time to which we may lend our consideration and effort.

* The more onerous duty of properly supervising a technical bureau is noted in a recent report of a committee of the National Academy of Sciences. Irregular methods of business are encouraged by general regulations which cannot be adapted to the special requirements.

In the fiscal year ended June 30th, 1882, the number of engines shipped did not exceed 133, the estimated value being $1,455,717. Of the 282 locomotives exported from the United Staies in 1883–4, 65 went to the Argentine Republic, 49 to the United States of Colombia and Panama, 34 to Mexico, 32 to Brazil, 27 to the Dominion of Canada, 19 to Chili, 14 to Australia, 13 to Central America, 14 to Cuba, 6 to Spain, 3 to San Domingo, 3 to Sweden, 2 to Venezuela, and 1 to England. The number shipped in the fiscal year ending June 30th, 1881, was 99; in the year 1882, 133; in the year 1883, 219; and in the year ending June 30th, 1884, 282. During the ten years ending with June 30th 1884, the Americans sent 434 locomotives to various parts of South America, 203 going to Brazil, 84 to Colombia, 72 to the Argentine Republic, 37 to Peru, and 31 to Chili. During the same period of ten years, Canada and British Columbia imported 208 American locomotives, valued at £381,626; Mexico, 167, valued at £361,740; Australia 113, valued at £215,834; Cuba 88, valued at $772,911; Russia 58, valued at $778,500 Central America 22, valued at £21,644, and Turkey 12, valued at £36,400. It seems very remarkable that countries oppressed with heavy protective duties should be able to compete so successfully with free-trade England. Political economists would do well to supply an explanation.

TOPOGRAPHIC SURVEYS OF STATES.

By H. F. WALLING,

Member of Boston Society Civil Engineers.

The initiation of co-operative State surveys in this country having inaugurated a new departure in topography, a complete history of previous efforts in this work throughout the country would have a special interest at this time. Not having the requisite data, however, I can only speak of them in a brief and imperfect way.

Up to about 1850, such maps of the older States as had been published were nearly all made at the cost of the respective State Governments, or were liberally patronized by them. This was the case in New York, Pennsylvania, Maryland, Virginia, Georgia, Alabama and Mississippi. The maps of these States were in general compilations from the plans of original land surveys. In 1844, Massachusetts caused to be published an exceptionally good map of the State, from special surveys made at the cost of the State and of the several towns. The geodetic basis of this map was the triangulation of Mr. Simeon Borden, and, as you are aware, it was a very well executed work. The details of topography, however, were worked out by the local town surveyors, whose methods, as might be supposed, were incongruous and generally defective, producing results which fell very far short of the precision which accompanied Mr. Borden's work. In spite of this imperfection, however, the map as then published far excelled any other State map in general accuracy and completeness of detail, nor does it suffer, considering the difference of scale, in comparison with the original Ordnance map of England. From the year 1850 up to the commencement of the civil war in 1861, and for some ten or twelve years after the close of the war, the demand for maps giving more local details than had been shown upon previous maps became sufficient to induce surveyors to engage in their publication, a portion of the expense being in some cases defrayed by State, county or municipal appropriations. Maps of towns and counties, afterward compiled into State maps, were made in this way, almost entirely from original surveys, in all of the New England States, New York, Pennsylvania, Ohio and Maryland. Large maps of some of the States west of Ohio were also published from time to time. Since the construction of these Western maps consisted principally in compilation from the United States Land Survey plans, the labor in preparing them was much less than in the Eastern States.

Commercial Maps.—Maps made with no means of defraying the cost other than from proceeds of sales have been styled "commercial maps," in distinction from maps produced at the cost of Government, the surveys for which are sometimes called "scientific surveys;" but I think the propriety of the designation is, in some cases, questionable. A survey may present the general features of the country with a considerable degree of accuracy, but if the details are erroneously represented in important respects, it is manifestly an incongruity to denominate such work a scientific survey. A comparison of some of the Government surveys of Western territorial regions, where two independent surveys overlap each other, proves by their discrepancies the inaccuracy of one or both the surveys. On the other hand, comparisons of some of the commercial maps with subsequently published Government maps, shows close correspondence, and as there is no reason to suppose that the latter are copied from the former, it follows that even a commercial map may be worthy of credit so far as it goes.

It should be observed that until quite recently *all* of the maps heretofore published in this country, whether by the Government or by individuals, with a very few exceptions, are destitute of accurate hypsometric information. The more notable exceptions are the topographic work of the United States Coast and Geodetic Survey, of the United States Geological Survey, principally in the Western territories, of some mining engineers who have made admirable maps

showing portions of the anthracite coal fields of Pennsylvania, and of the Second Geological Survey of Pennsylvania in special maps of limited areas in that State.

The wholesale condemnation which certain scientific critics have from time to time bestowed upon commercial maps, as such, not discriminating between those which have been carefully made from original work and other mere compilations from Government explorations, etc., which perpetuate from year to year, the original errors of their sources of information, indicates an unjustifiable lack of knowledge on the part of the critic, of the amount of original and really valuable information which some of these commercial maps embody. They have rendered valuable service to railroad and hydraulic engineers, to county and town officers, and even to geologists and other naturalists and scientific investigators. Besides these, many intelligent citizens, realizing the value of the maps for their own more private uses, have, by bestowing their patronage upon the surveyors, enabled them to publish these maps. If competent experts found on examination that these maps were erroneous and unworthy of credit, it would be their duty, in behalf of the public, to expose their unworthiness by pointing out the inaccuracies, etc. But it is hardly justifiable to condemn them *en masse* merely on account of their self-sustaining origin, or because the mechanical execution was not upon so expensive a scale as might have been possible under more favorable conditions. My apology for bringing this somewhat unprofessional subject before the Society is a feeling that injustice has been done to a number of local map makers in the New England and Middle States, who at their own cost and risk, during the last thirty-five years, have materially added to the previous knowledge of local topography, so far, at least, as it pertains to horizontal relations.

County Maps of Massachusetts.—I now beg your further indulgence for a brief account of some of the methods employed in my own work in Massachusetts some thirty years ago. This is done principally for the purpose of showing what can be accomplished at a comparatively small cost. It is not cited as an example to be followed, but rather as one whose faults and shortcomings are to be avoided when the means of carrying on the work in a better manner are available.

Having previously made surveys and maps of a number of towns and cities in the State, which were generally paid for by municipal appropriations, I undertook in 1854 the construction of a separate map of each county in the State, excepting the small counties of Suffolk, Dukes and Nantucket, which were included on sheets containing larger adjacent counties. The materials then in existence for such as set of maps included, first, the excellent triangulation made by Mr. Borden some fifteen years before, which had been used as the basis of the official map above mentioned; second, the town surveys ordered by the Legislature and made in 1830 and 1831, from which Mr. Borden compiled the details of his map; and third, more recent town and city maps, including those made by myself, already mentioned. The latter material was to be used, so far as it went, but it constituted a very small portion of what was required. The old town maps, although drawn to a scale two or three times as large as was proposed for the new county maps, were, in many respects, too inaccurate for use. A new survey was accordingly undertaken of all the public highways in the State. A careful estimate of the possibilities of remuneration limited the cost of the survey, including field and office work, to about one dollar and a half per square mile; and, ultimately, this was about the average cost. Hypsometry, as a feature of topographic maps, was at that time only undertaken in a few European Government surveys, made at great expense; and while I fully recognized its value, it was, of course, excluded unless the cost could be defrayed at public expense.*

* Before undertaking the work as a private enterprise, I had attempted to procure State legislative action in its behalf, and the subject was referred by the General Court to their Committee on Education. Professor Arnold Guyot, then a resident of Cambridge, and Mr. Simeon Borden kindly interested themselves in the project which I presented, and urged upon the committee the acceptance of my proposal to make a hypsometric survey by tachiometric methods—that is, by the use of graphic triangulation stadia, vertical angles, etc., in connection with traverses of the roads, at a cost of $25,000. These tachiometric methods had then recently been introduced in Europe by M. Porro, a noted Italian topographer. The committee reported a resolve authorizing the survey as proposed (see House Doc. 170, Mass. Leg.,

The scope of the work I had undertaken included the representation of roads, railroads, streams, ponds, marshes, the sea coast, with its capes, bays, inlets, and islands, and of important buildings, including dwellings, churches, schoolhouses, mills, manufactories, stores, etc. Some hachure sketches of prominent hills, in accordance with the imperfect fashion of the time, indicated the existence of slopes, more or less steep, and served to show where high ground or rough country was to be found, but gave no definite information in regard to actual heights or the true forms of relief. Fortunately, the entire coast line of the State was shown on the published or manuscript maps of the United States Coast Survey, together with a narrow strip of the adjacent land. So far as it went, this data was all that could be desired. The town maps furnished to the State archives, according to law, in 1831, in advance of Mr. Borden's triangulation, gave representations of town boundaries, roads, streams and ponds. These representations were fairly correct in the groupings of the various features in regard to the relative positions of objects when referred to those immediately adjacent, but owing to the imperfect methods of surveying and want of skill in platting or graphic representation, the map of a town, as a whole, was frequently more or less distorted and deformed. This was readily detected by the discordance between maps of adjacent towns along common boundaries and the impossibility of fitting a number of maps together into a larger continuous map. Since these maps, however, were made by local surveyors, whose knowledge of the general relative positions of roads, streams, water surfaces, etc., would be likely, from the nature of their occupation, to be as thorough as that of any class of people, and, in the main, correct, I made use of them to some extent for drainage representation, etc., under a careful system of checks, to be hereafter described.

Having for the basis of the proposed county maps the Coast Survey and Mr. Borden's triangulations, the plan was adopted of traversing all the public highways by course and distance, using the ordinary surveyor's compass for directions, and the revolutions of a wheel for distances. I wish to say a few words here in regard to the comparative usefulness of a wheel for measuring distances along roads. Though less accurate than a chain in the hands of skillful chainmen, it has the merit of economy, since one person with a compass and odometer can do the work of a party of three with a compass and chain. Then, the inaccuracies due to the inequality of the surface are much less on common roads than, in the absence of tests, would be supposed. In fact, on the ordinary roads of Massachusetts, which usually change their directions in short distances, the error from this cause becomes inappreciable in platting to a scale not larger than $\frac{1}{20000}$, except in long, straight stretches of hilly road, Moreover, there is little or no liability to an accumulation of errors of counting or reading, as with the chain or stadia. For example, if an error were made in reading the dial of the odometer, which usually registers from zero to 1,000 revolutions of the wheel, the error would not accumulate, but would be taken from one adjacent course and added to the other, so that if the change in direction was not great, the resulting error would be slight. In fact, where readings are frequently made in noting features of local topography, buildings, stream crossings, etc., an error of reading is often detected by its incongruity with adjacent readings. In stadia measurements, the distances must be reduced to horizontality, and in ascending or descending, unless the rod is held perpendicular to the slope, another correction becomes necessary, if absolute precision is required. But for traversing across fields, meandering streams, etc., the wheel is unavailable, and, for topographic work, stadia measurements seem preferable to any known method for rapidity and convenience. By the system of traverses adopted, all the highways were surveyed and platted continuously in a network. Each closed circuit of this network not only checked itself, but served to check adjacent circuits. Usually the errors of closure did not exceed one or

1854), and it had many friends in the Legislature; but the party in power had not the courage to risk being charged with extravagance by their opponents, and the subject was, by a small majority, referred to the next Legislature, where another resolve was reported favoring the work, which was again referred, however, to the succeeding Legislature (see House Doc. 294, Mass. Leg., 1855).

two per cent. of the distance traversed. An abnormally large gap in the closure of a circuit was checked by the closures of adjacent circuits until its approximate locality was established between two adjacent road junctions, where, by carefully studying the notes, comparing the sketched with the platted angles, the error was, in most cases, detected, being found due to some obviously erroneous reading of the compass or odometer; and finally the few undetected errors, when sufficiently important, were corrected by a resurvey of the defective portion. Upon the final adjustment of the network of roads, the other details of topography, namely, the dwellings, streams, etc., were supplemented. The field notes were first platted upon a scale of $\frac{1}{20000}$, that of the published maps varying from $\frac{1}{40000}$ to $\frac{1}{63360}$.

In order to reduce the work to a geodetic basis, and, as far as possible, to eliminate errors arising from inaccuracy of standard, etc., the traverses were connected with all the primary and secondary stations of the trigonometric surveys, which could be identified upon the ground, and these stations were marked upon the platted network of roads. Parallels and meridians were then interpolated between the stations for each minute of latitude and longitude, giving the residual seconds their proper value, and dividing the remaining spaces into the proper number of equal parts. A true projection in minutes being made on the publication scale, the original draft was reduced into its proper place, square minute by square minute. The ratio of reduction from the original draft to the publication scale agreed very closely, showing the general accuracy of the standard and of the graphic work, the difference being hardly greater than might have been caused by hygrometric changes in the paper.

This brief outline of methods and checks used in the construction of county maps in Massachusetts, now more than twenty-five years old, will give some means of judging whether or not they possessed a value commensurate with their cost in the more exact delineation than had previously been made of horizontal relations between the objects represented. It is quite evident, however, that whatever may have been the character or usefulness of the maps then made, the time has arrived when better methods and more precise results are required. While it is by no means necessary or advisable to entirely discard the method of traversing by which all the minute sinuosities of roads, streams, etc., are rapidly and economically ascertained, this method should be made subsidiary to the more exact processes of triangulation, which should be carried much further into detail than before.

Triangulation.

It is quite unnecessary to discuss before this Society the superiority of triangulation over traverse measurements as a means of determining positions. Starting from a base line measured with the refinements now attainable, the large theodolites constructed for the great geodetic surveys of the world are capable of measuring angles to within a quarter of a second, a degree of precision which renders it possible, as is claimed for the geodetic survey of British India, to determine the ratios between the sides of a network of geodetic triangles to within a theoretic error limit of one two-millionth part of the distance determined. (Address of General J. T. Walker to the Geographical Section of the British Association for the Advancement of Science. See Van Nostrand's Engineering Magazine, January, 1886, p. 71.) In the geodetic work of the United States Coast Survey for the Eastern Atlantic States, the error limit does not exceed $\frac{1}{288000}$, or less than a foot in fifty miles. (U. S. Coast Survey Report for 1865, p. 195.) For secondary triangulation—that is, the cutting up of the larger geodetic triangles into smaller ones for use in topographic work, etc.—instruments reading to 10″ or even 20″ are considered sufficiently powerful, and with them a precision which would limit the error to one foot in five or ten miles should be easily attainable. Such instruments are not difficult to transport, and there seems to be no advantage in the use of smaller instruments for the preliminary triangulation of a topographic survey.

Graphic Triangulation.—Triangulation, however, in a well-conducted survey by no means ceases with the instrumental and computed work. It is carried on by graphic processes upon a plane

table until it reaches a stage where the triangles are sufficiently small to allow the interpolation of details by stadia measurements, pacing or even eye estimates and sketches. Stadia measurements must be regarded, moreover, as really belonging to the series of triangulation determinations in which the triangles are quite "ill conditioned," that is, the known base, read off from the rod, is very small compared with the required side, or the distance between the reading instrument and the rod. The solution of these triangles by simple inspection sustains a relation to computation work similar to that of the slide rule. Such measurements can only be used to advantage for comparatively short distances, one thousand feet being about the maximum distance from the instrument at which distances can be read with sufficient precision.

Eye Estimates.—Eye estimates, even, are a species of triangulation. They are probably made by an unconscious comparison of sensations which accompany an adjustment of the focal length of the crystalline lens supplemented by a stereoscopic adjustment of the optical axes of the two eyes.

They are aided, where circumstances will permit, by comparisons of spaces occupied upon the retina by the images of fences, buildings, trees, animals and other objects of known size at different distances. Another aid to eye estimates is found in "aerial perspective," as it is termed by artists, or a certain haziness caused by minute opaque particles in the air, tinging objects with a purplish color, gradually changing to a blue approaching that of the sky as the distance increases. This change of color and the gradual loss of distinctness and merging of objects into each other afford a rough measure of relative distance.*

The bases of the triangles in the cases of eye adjustment are, first, the diameter of the crystalline lens at its opening, and, second, where the stereoscopic adjustment is made, the space between the two eyes. It must be remembered that there is no cotemporaneous scale of comparison for eye estimates. They are only obtained by a comparison of present sensations with former experiences, in which distances were estimated and verified by reliable measurements. It may be questioned, even, whether eye adjustments can practically be made in absolute conformity to the distance, and whether attempted adjustments are not affected by the personal condition of rest, fatigue, excitement, etc. It must be admitted, however, that in this, as in other uses of the senses, continual practice will be likely to lead to a remarkable degree of skill. Some of the topographers of the Geological Survey, for example, have attained an eminent degree of proficiency in eye estimation, and are able to sketch upon their field sheets the topography within a radius of several miles around each station occupied, and sketches so made are said to fit each other fairly well where they join or overlap. Where the limit of time and cost renders it necessary for each topographer to cover some thousands of square miles in a season with a sketch map of previously unexplored country, which shall give a general view of its salient features until a more careful survey is available, the use of "sketching stations" and eye estimates over such extended areas may be unavoidable, but it is quite evident that for State surveys such estimates must be limited to short distances and for the location of comparatively unimportant objects.

When at length the triangulation processes, including estimates of distances, cease, the topographer completes his work by sketching in from point to point the irregular curves which express the contours of the surface. Here his success depends upon a sense of form and proportion comparable with that of the landscape or portrait painter.

Amount of Preliminary Instrumental Triangulation Needed.—We are now confronted with the question, how much instrumental and computed triangulation should precede the final graphic or plane table work in the survey of a comparatively well-settled State, like the New England States, New York, New Jersey, Pennsylvania, etc.? This will depend in part upon the scale of the map to be constructed, since the scale will govern the

* In the discussion which followed the reading of the paper, Mr. Fred. Brooks remarked that the distances of objects seen across water were deceptive, owing to the absence of objects of comparison, and that an unusual clearness of the air in mountain regions caused distant objects to appear nearer than they really were.

area to be included in the field sheets, which may conveniently be used. It is considered indispensable that each plane table sheet shall contain at least three precisely determined points, laid down upon it in advance of its use in the field, two of them serving for a base, and the third for verification. These three points should be spread apart in an advantageous manner, be intervisible and command views of other controlling points coming within the limits of the sheet and suitable for occupation. While in skillful hands and with a good plane table, the accuracy with which triangulation may be performed is commensurate with the scale of the work, it is also true that many advantages would accrue from having numerous well chosen points located upon the sheet with the precision of numerical computation, since it is evident that the topographer could then proceed with certainty and dispatch to fill in the spaces between the smaller triangles thus formed; but the cost of graphic triangulation being somewhat less than that of the computed work, the question where the latter shall cease and the graphic work commence becomes one of relative value and cost. The cost of the field work for determining stations more than two or three miles apart is not greatly different in the two methods, but the additional cost of computation swells the expense of the instrumental method. Some of the principal officers of the United States Coast and Geodetic Survey hold to the opinion that at least one computed position should be given in every square mile of area for the best results in plane table work. Other skillful topographers are satisfied with stations three or four miles distant from each other. If, as in Massachusetts, the monuments marking angles in state, county and town boundaries are to be determined by computed triangulation, these determinations, with the auxiliary stations needed to reach them, will furnish points averaging less than three miles between adjacent stations and will constitute a sufficient amount of secondary triangulation to precede plane table work and enable the topographer to carry it on with rapidity and precision.

Utility of a Triangulation Basis in Civil Engineering.—Mr. Borden, in making his careful triangulation of Massachusetts, considered that one of its most valuable uses would be to serve as a basis for the work of civil engineers and land surveyors, who would thereby attain a high degree of precision in extended surveys, as well as a means of connecting independent surveys together with almost absolute certainty. Accordingly, for the use of surveyors, etc., he not only computed the geodetic co-ordinates, or latitudes and longitudes, but gave rectangular co-ordinates from convenient reference points. It is obvious that these data are more simple and better adapted for the use of civil engineers, while over limited areas their precision is not sensibly impaired by the curvature of the earth's surface. But his primary stations were too far apart to be conveniently used in this way, and the time had not arrived when the advantage of co-ordinate determinations would be sufficiently appreciated by civil engineers who had been brought up in less reliable methods. There were a few exceptions, however, including ex-President Doane of this Society, and some of his pupils, who systematically referred their surveys to the co-ordinate axis used by Borden in this vicinity, namely, the meridian of the State-House dome and a line at right angles to it. Some of the extended maps of surveys for the water supply of Boston are similarly referred. At the present time, many town and city engineers, including several members of this Society, have expressed their intention to connect their work in a general co-ordination, as soon as the secondary triangulation, which is expected as a preliminary to the present topographical survey of the State, shall bring stations within their convenient reach.

Under prevalent methods of surveying, great uncertainty often arises in attempting to re-locate lines where monuments have been lost or displaced; but, if carefully connected with an extended triangulation, the uncertainty disappears, and the work is effectually removed from the arena of dispute and litigation by the certainty with which the controlling positions may be restored from the triangulation stations. In those cities and towns where cadastral surveys are to be undertaken, the advantage of such a basis for the work is obvious. In fact, a continuous survey, for any purpose, ex-

tending over a considerable area, can best be rendered consistent with itself and its surroundings by basing it upon an extended triangulation, and bringing it into a general system of co-ordinates.

There is another consideration which should not be overlooked in discussing the amount of preliminary triangulation needed in State surveys. In many populous districts the questions of water supply and sewerage are pressing with great force upon public attention. Surveys are likely to be needed for the investigations called for, involving a higher degree of precision than the limit of cost fixed for the State survey would cover. A true economy would seem to require that as much as possible of the work done should be available for such future exigencies. An exact instrumental triangulation would cost but little more than imperfect graphic work, whose occupied stations would be unavailable for any subsequent surveys, while the computed positions would serve as reliable reference points for all future work.

On the whole, it would seem that a wise view was taken of the proper functions of the General Government when authority was given to the Coast and Geodetic Survey by Congress to furnish State governments with secondary triangulation brought to a sufficient degree of minuteness to meet the requirements of topographic work. With adequate appropriations to sustain the authority thus given, there ought to be no difficulty in solving the question as to where secondary triangulation should end and graphic work commence. A proper co-ordination between the geodosists and the topographers in this respect would diminish the labor and cost of topography while augmenting the precision of its results.

Subsidiary Traverse Work.—A skillful topographer, accustomed to the constant use of the plane table, will not readily admit the need of subsidiary work in which field notes and subsequent platting are required. Upon scales as large as $\frac{1}{10000}$ or $\frac{1}{15000}$ the topography may all be drawn directly upon the plane table. Where streams and roads in wooded regions are to be shown, with all their sinuosities, traversing is resorted to, care being taken to connect the traverse lines as frequently as possible with the triangulation points. By orienting the plane table at each angle and measuring distances with the chain or stadium rod, traverses may be made without resorting to field notes. When, however, the scale is diminished to $\frac{1}{20000}$, or smaller, and a more rapid progress over a given area undertaken, a considerable saving of time is effected by resorting to extra field notes for roads and streams, using a light instrument for angle measurements. The field notes might be dispensed with, perhaps, by using a light and portable supplementary plane table, having, however, sufficient stability to permit a few observations at each point occupied without disturbing the orientation, which might be maintained by using a declinometer or magnetic needle. In this way all objects visible from the line of traverse could be rapidly laid down, and the drawing compared on the ground with the objects represented, an advantage over platting from notes that topographers will appreciate. The light plane tables used for mountain work by some of the topographers of the United States Geological Survey seem adequate for this subsidiary traversing, which might be carried on by the younger members of a party. They will usually find more satisfaction in adopting a larger scale than that of the large plane table sheet, to which their work can easily be reduced by proportional divides when ready for transfer.

HYPSOMETRY.

Besides attaining a general co-ordination of results in two dimensions with a greater degree of accuracy than most commercial maps, constructed from traverse surveys, exhibit in the horizontal representation of surfaces, government surveys are now expected to take the third dimension into account by presenting *vertical relations.* These are best expressed upon the maps by a series of lines corresponding to the intersections of certain imaginary level surfaces with the surface of the country represented. The first or lowest of these surfaces, as adopted by the United States Coast and Geodetic Survey and the United States Geological Survey is that of the ocean supposed to be at rest in the absence of tidal influence. The intersection of the mean sea-level with the land surface, cor-

responds to the coast line at mean half tide. Imagine the ocean to be raised twenty feet higher, still undisturbed by tides, and draw the new coast line upon the map. Let the ocean be again and again raised, each time twenty feet higher than the last. The successive coast lines thus formed and drawn upon the map would represent lines having the same height throughout, to which the name "contour lines" has been applied in hypsometry. An objection to this name is that it does not convey the idea of equal height, and might be applied with equal propriety to other than horizontal outlines; for example, to a vertical profile, or to the outcrop of an inclined strata, etc. A word given in Greek lexicons, namely isohupes (ισουψης) a compound word signifying equally high, would more nearly express the meaning intended. Other intervals between the successive isohupes might be adopted to suit the circumstances of scale, steepness of slopes, etc. The topographers of the United States Geological Survey show isohupes upon their territorial maps with differences of level from one hundred to two hundred and fifty feet. Upon their surveys of Massachusetts and New Jersey the interval is twenty feet, and the same interval prevails in the topographic work of the United States Coast and Geodetic Survey.

Leveling.—The most accurate known method of ascertaining differences of height is by means of the spirit level, but to carry this method into all the details of a State survey would be far too laborious and expensive, especially where the changes of level are frequent and considerable in amount. It use may generally be limited to the running of a series of check lines across the surveyed area, and establishing thereby a system of bench marks to which levels determined in other ways may be referred.

Bench Marks and Reference Levels.—As in determining the horizontal relations of objects a preliminary triangulation is necessary to fix a convenient number of reference points, so in a hypsometric survey, equal or greater care should be exercised to provide in advance reliable bench marks to which the heights of objects may be confidently referred. A failure to do this will sooner or later involve the work in confusion. In geodetic operations it is usual to determine the relative heights of all the triangulation stations, by measuring vertical angles or zenith distances from one to another. A fair degree of precision is attainable in this way, the most important vitiating factor being the unequal refraction of the visual ray while passing through air in variable degrees of density. In Massachusetts this method was pursued by Mr. Borden, as well as by the United States Coast and Geodetic Survey, with nearly coincident results, where the stations were identical.

Precision in Hypsometry.—The practical uses to which hypsometric information is applied require even greater precision in height determination than in the horizontal relations of topography. An error in the designated height of a stream at any particular point would be more important than the horizontal displacement of the point to a considerably greater extent. Questions of water-power, for example, would require for satisfactory solution a pretty exact knowledge of the amount of fall in the stream. Indeed, the horizontal displacements of incorrect isohupes would, in general, be far greater in amount than the vertical errors involved. It is seldom in nature that slopes are found so steep as forty-five degrees, or a unit of base to one of height. A slope with a base of six horizontal to one vertical on a road would be considered steep. Here the horizontal displacement would be six times the vertical error, and this ratio increases rapidly as the slope approaches to a level.

Hence the necessity appears for an increased precision in height determinations where the surface of the country is made up of gentle undulations. It is also evident that the instruments used for determining differences of level across a State should be capable of a high degree of precision. Since the alidades usually accompanying plane tables are supplied with vertical circles only reliable for comparatively short distances, the necessity for frequent well-determined bench marks presents an additional reason for carrying on the secondary triangulation with the theodolite, including height determination by vertical angles in advance of the graphic work, as far as the expense limit will permit.

Engineering works already constructed in the older States, more especially the railroads and canals, were usually preceded by leveling surveys made with much care. From these surveys, profiles showing the inequalities of the surface were drawn with the heights marked in feet above some reference or datum level. Upon the profile of a railroad, its gradients and the amount of cutting and filling along the line were established. On the completion of the road, its profile, if well made, would accordingly show the exact rate and amount of its successive rises and falls, and the absolute height of any point above the datum level.

The simplicity of the work, and the obvious necessity for a reasonable degree of precision to avoid ultimate confusion, would seem to warrant the expectation that railroad profiles might be used to great advantage in hypsometry. But, on comparing the profile of intersecting roads, many discrepancies are found, arising partly from uncertainties as to the datum level adopted, and partly from a want of care and skill in the preliminary work.

Fortunately, leveling surveys can usually be carried with much greater facility along the roadbeds of railroads already constructed, than over the uneven original surfaces. Much perplexing uncertainty would be avoided, and the work of a topographic survey greatly facilitated, by the comparatively inexpensive expedient of carrying preliminary lines of level across the State, and across each other along the main lines of constructed railroads. In this way they would check each other, and afford the means of correcting and adjusting all the connecting railroad profiles to a common datum level. These profiles should be connected with the trigonometrically-determined points at convenient places, in order to unite all the data into one reliable system of reference heights.

Where as in many parts of New England, the water power of rivers is fully or in great part utilized, preliminary connections should be made with the surfaces of mill ponds or the crests of dams along manufacturing streams. Here the owners of mills have generally taken measures to ascertain the exact relative height of their own dams and of those above and below them, the value of their water privileges depending upon units of differences of level. In Massachusetts, accurate profiles are in existence of such rivers as the Connecticut, Merrimac, Charles, Sudbury, Nashua, Blackstone, Housatonic, and others. Surveys for the water supply of cities and towns generally include carefully-executed levels of great hypsometric value in the regions thus investigated.

Of course, for connecting all these levels with the mean level of the sea, access must be had to the sea coast, where, to obtain the mean level, observations are needed of high and low water. For great precision, a long series of observations is requisite. These, however, have been made, and bench marks established in many of the ports and harbors along the coast, by the United States Coast and Geodetic Survey.

Plane Table Hypsometry.—Having the preliminary data for location and heights carefully established, the topographer is prepared to take the field with his table, secure from the confusion which would attend an inadequate and uncertain determination of positions and heights. The determination of heights in plane table work is almost entirely by means of vertical angles, the alidade of the instrument being provided, for that purpose, with a small vertical circle. On account of the greater precision required, heights are not, like horizontal determinations, obtained graphically. The angles are instrumentally measured, and the distances being scaled from the map, the differences of level are computed or taken from tables. A more convenient method than either might be found, perhaps, in the use of a specially designed slide rule. Without going into the details of plane table methods, it is sufficient to say that the height of each plane table station having been determined, either before occupation, if located by intersection from other stations, or immediately after, if located by resection or by the three point method, is used in turn to fix the heights of all points determined more or less directly from the new station. If the preliminary work has been properly done, and the topographer is skillful in selecting his points of occupation, he will always have several determined points in view from which he

can find with certainty both his horizontal position and its height. Spires, cupolas, gables, chimneys, flag-staffs, remarkable trees, rocks, etc., afford good reference points, and their heights at the top, or at some conspicuous point like a weather vane, etc., having been determined, they also form good bench marks. As fast as positions are located upon the plane table sheets, their heights should be marked and the adjacent isohupes interpolated between them. *This should invariably be done in the field*, not left for future office work, which at best is likely to fail in the critical places where the characteristic expressions are to be brought out. Attempts to make character sketches by conjectural contours of indefinite height are sure to fail if not based upon exact truth. True isohupes, with rare exceptions, are themselves the best character delineators. Auxillary lines with smaller intervals may be interpolated between the isohupes of regular intervals, where some peculiarity of feature would fail to be otherwise expressed, and a skillful topographer sometimes takes the liberty of slightly displacing an isohupe from its theroetical position to secure an expression of nature which the true isohupe would fail to bring out, owing to a certain neutrality due to its arbitrary height, somewhat above or below that of the characteristic feature.

Comparative Utility of the Plane Table.—Enough has been said, perhaps, to show the advantages of the graphic method of representing topographic details when compared with the use of field notes and office platting. A topographer who has become familiar with the use of the plane table cannot easily be persuaded to adopt other methods for his special work. Even under unfavorable circumstances, for example, where the geodetic and secondary triangulation points are widely scattered, and extensive vistas are precluded by numerous wooded areas, he will carry in from outside bases a chain of graphic triangulation, extending it between the wooded patches until he finds a check by coming again to previously determined bases. The accuracy of such work is far greater than can be expected from traversing between the widely separated, non-graphic triangulation stations, especially where directions are referred only to the magnetic needle. Of course, well executed previous surveys may sometimes be incorporated into the work with advantage; as, for example, where accurate maps of the compact portions of cities and populous towns are found. These can usually be reduced to the required scale, and after laying down a few of the principal streets by the graphic methods, the remaining network of streets, etc., can be fitted into its proper place. Much assistance may be derived, in locating railroad lines, especially where the curvature is complicated, by platting the engineer's alignment to the scale of the plane table sheet, and fitting it between points graphically determined. The advantages of the graphic method, especially in the projection of isohupes, would obviously be lost, however, if any considerable part of the work were left to be completed, after leaving the ground, by platting field notes or sketching from memory. Besides the loss of time, there is the large element of uncertainty which usually attends the deciphering of sketch notes after they have become "cold" by lapse of time.

As the success of the portrait painter is measured by his skill in reproducing not only the more striking and familiar features of his subject, but a certain subtle, undefinable expression of individual character, so the topographer is a true artist who brings out upon his map not only the salient contours of the country, but the less apparent though real markings, which reveal to experienced eyes the conflicts of the past between the great sculpturing forces of nature and the rugged resistances which have opposed them, the effective touches in either work of art being applied *in the presence of the subject portrayed*, with a true artistic sense of form and proportion.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS—FEBRUARY 17th, 1886.—A paper by Clemens Herschel, M. Am. Soc. C. E., "On the Work Done for the Preservation of the Dam at Holyoke, Mass.," in 1885, and on some studies for a new stone dam for the same place, was read by the author and discussed.

The paper opens with an account of the Water Power at Holyoke. The charter of the Hadley Falls Company was obtained in 1847, one of its purposes being the building and maintaining of a dam across the Connecticut.

The first dam was intended as a temporary one, to serve as a protection during the erection of a more substantial one below it. It was not able to resist the force of the river, and was carried away a few hours after the gates were closed. The construction of this dam is not known to the author

The second and present dam was begun and completed in the summer of 1849. It is 1,017 feet long. At the ends are abutments of heavy masonry. Between these abutments it is composed of heavy timber crib-work, the surface on the upper side being inclined 21° 45′ to the surface of the river. The timbers are bolted to the rock bottom with about 3,000 one and one-quarter inch iron bolts. The foot of the dam was protected with gravel covered with a mass of concrete. All open spaces were packed with stone to a perpendicular height of about ten feet. The graveling in the bed of the river began seventy-feet above the dam, and was continued over thirty feet or more of its sloping surface. The fall from the river above the dam to still water below is 59.9 feet, there being a perpendicular fall of thirty feet. The total cost is given at $150,000. The chief engineer was Philander Anderson. The maximum height of water over the dam, from its completion to the present time, has been 12½ feet in 1862. Only ten feet had been provided for in the construction. The dam is built on a ledge of red slate, which in places becomes a hard red sandstone. This dips down stream at an angle of about 30° with the horizontal. In 1868 an examination showed that the fall, aided by logs, etc., had washed out the ledge in front of the dam to a depth of 20 to 25 feet, and had in places worked back under the foot of the dam, partially undermining it. In 1868 to 1870 an apron was built down stream from the dam, its volume far exceeding that of the original dam. It was built of round logs laid so as to form bins six feet square, which were filled with stone to the top. This protected the dam from further undermining, but a new "pool" was soon excavated below the apron, which is now 20 to 25 feet deep at the deepest parts.

The dam then continued to do its work until, in 1879, there appeared a well-defined whirlpool above its crest, and examination soon showed a break through the plank covering at that point. This and subsequent breaks were repaired by means of cribs, made like a box without top or bottom, the under side being cut to a bevel, so that when resting on the back of the dam the upper side would be horizontal. In 1881 there were two new breaks, which again broke through in 1882. There were no breaks in 1883, but in 1884 a large one appeared which could not be covered with the 20×35-crib of 1882. A crib, 40×45 feet, was accordingly built, the whole being completed in 19 days. Details of the operations of setting the cribs and repairing the breaks are given. One serious objection to this method of repairing the dam was the liability to make new breaks in repairing those already made. As the dam was all of the same age, the occurrence of much more serious breaks was probable, and the proper course for the future became a question for earnest consideration.

The first project was to sink cribs on the dam, cut through the covering and fill it with gravel well washed in. Plant was accordingly prepared, and in December, 1884, the work of filling was begun, but owing to the severity of the weather no progress could be made, and the work was discontinued until after the spring freshets. This gave an opportunity for a careful study of the whole subject. This was made by the use of models, the use of which is earnestly recommended by the author as in many cases superior to drawings.

The plan finally adopted was by the use of coffer-dams, to lay bare a space 20×100 feet next the crest of the dam, and remove the covering. Sheet piling was then carefully placed against the up-stream face of horizontal timbers of the crib-work of the dam, so as, with the solid course formed by the crossing of the timbers forming the "bins," to constitute a continuous line of sheet piling lengthwise of the dam. Gravel was then dumped each side of the sheet piling, and washed down until no more could be put in. The covering was then restored, and the coffer dams moved to the next section.

In carrying out this plan, the gravel, *debris*, etc., on the surface of the dam had first to be removed for the placing of the coffers. The plan finally adopted for this was to have divers wash the material into windrows with a stream at 80 to 90 pounds pressure through an inch nozzle. This was then removed by a very small clam-shell dredge. Three divers and the dredge finally cleaned 120 feet of dam in about four days. The author comments on the great value of employing divers in many classes of work under water.

He insists on the use of a check valve in the helmets of divers, and of a telephone between diver and tender. Two divers were lost on the work, one of whom would have been saved by the use of a check valve. After the surface of the dam was cleared, the coffer dams were put in place, and the joints made tight by spiking on planks. With the aid of the floating derrick two coffers could be set in place in one day. Before placing the planks of the sheet piling, the "bins" were dug out, or the stone picked out by hand, as low as the water would permit, this being throughout several feet lower than the old stone filling put in in 1849. With the exception of driving the plank into the old filling about a foot, they were carefully set by hand and well braced against the opposite face of the bin. The bottom averaged from 25 to 28 feet below the crest of the dam.

The gravel for filling on each side of the plank was from a pit about two miles away. It was shoveled into dump buckets which were carried on cars to the work, where it was dumped from the same buckets. The average cost for wages was 46.6 cents per cubic yard, about 15 cents of this being for railroad service. The gravel was washed down as dumped, by water from three lines of hose tapped into the coffer dam. The total amount of gravel put in was about 13,000 cubic yards.

As a result of the work done, further breaks as heretofore understood are impossible or of no consequence; the timbers being encased in

solidly puddled gravel, are permanently protected against decay, and the leakage has been reduced to about one-tenth of what it was before the break of 1884.

The first half of the dam was repaired in about three months, the last half in one month, and usually on a work of this sort the author considers triple the speed at the end from that at the beginning, generally attainable. Electric lights were used on the work and proved of the greatest value. No difficulties were encountered in closing the last section, this being perhaps due to the fact that that side of the river had filled in much more than the other shore or the middle part. It was well-known, too, that the leakage of the middle 200 feet of the dam was much worse than the rest. The cost of the work is estimated at about $65,000, including the cost of plant. It cannot be precisely stated, because the repairs of 1884 and the break of 1885 were charged to the same account.

The author deduces the following as the lesson of 1849 to 1886 in the construction of wooden dams: 1st. A wooden dam should never be left hollow, nor should it be filled with stone. Let a row of sheet piling be put in in some proper position, then puddle in gravel. 2d. In crib work two timbers should never be butted over another of the course next underneath. 3d. Never substitute masonry for the frame of the dam next to the abutment. 4th. The back of the dam should be guarded from such abuse as the dropping of 4-ton stone upon it. 5th. The shape of a dam should always be chosen with a view to preventing the excavation of the river bed, and the formation of a pool below the dam. In this connection the author made experiments with models one-twelfth full size to determine the proper form for a new stone dam at Holyoke. The ogee form gave the best solution of the problem. A reverse incline is necessary at the foot of the dam sufficient to destroy the acquired velocity of the water, and project it in a horizontal direction parallel to the bed of the stream, or the bed of the stream should be protected. The author learned, while writing this paper, that the Croton Dam is of this form. There is also a dam of an ogee shape in Spain.

MARCH 3d, 1886.—A paper by Fred Brooks, M. Am. Soc. C. E., on "Thermometer Scales," was read and discussed. The author advocates the discontinuance of the use of the Fahrenheit scale for temperature, and the adoption for all uses of the centigrade scale. There are few or almost no obstacles to this course. Conversion tables are abundant; its use is more especially for scientific purposes; national prejudices are not excited; it is independent of other measurements; the centigrade scale is already largely used, and it can be used by any one at once without a date being fixed in advance for its universal adoption.

A paper by H. V. Hinckley, M. Am. Soc. C. E., on "Errors in Railroad Levels" was read. The character of the leveling on the Atchison, Topeka and Santa Fé Railroad having been called in question, the author took measures to check the correctness of the levels by direct search and by checks from intersecting roads and reliable benches. The results are summarized as follows:

RAIL CIRCUIT CHECKS.

No.	From	Via	To	Miles.	Errors in Feet.	Errors. Feet per Mile.
1	Kansas City..	Topeka.....	Atchison.. ...	116	0.006	0.00005
2	Emporia Junc.	No. Topeka and Junction City.	Emporia Junc.	196	0.180	0.00092
5	Pueblo	La Junta and El Moro	Pueblo	246	0.580	0.00236
10	Deming.....	Albuquerque and Mojave	Deming.....	1,862	1 978	0.00106
11	Rincon	Deming and El Paso..	Rincon	218	0.190	0.00087

TIDE CHECKS.

3	Kansas City...	A. and P. R. Railroad.....	San Francisco.	2,115	2.04	0 00096
4	" " ...	A. and P. R. and S. P. Railroad	Pt. Ysabel	2,150	1.03	0.00048
6	" " ...	Deming.....	San Francisco.	2,347	0.062	0.00003
7	" " ...	"	Pt. Ysabel	1,686	0.948	0.00056
8	" " ...	Tombstone.....	Guaymas.....	1,657	3.390	
9	" " ...	El Paso.....	San Francisco.	2,459	0.128	0.00005

NOTE.—Discussion on the subjects referred to is invited.

ENGINEERS' CLUB OF PHILADELPHIA—RECORD OF BUSINESS MEETING, FEBRUARY 20th, 1886.—Mr. J. Foster Crowell presented, in continuation of his discussion of the Interoceanic Canal Question, an exposition of the engineering features embodied in the Nicaragua Ship Canal project in its latest form, illustrated by official maps and profiles of the country, harbors and route, accompanied by detailed plans of the dams, locks and other permanent structures furnished through the courtesy of Mr. A. G. Menocal, the chief engineer of the undertaking.

The paper began with a comprehensive description of the topography of the canal site, the great basin of Lake Nicaragua and the San Juan valley—claiming broadly the adaptiveness of the country to the purpose, and defining the

canal location, which, in the author's opinion, has been so contrived as to fully avail of what nature has already done.

He stated that in the limited sense in which the term canal is generally used, it is a misnomer for this work, which is to be "a slack water system of grand dimensions, wherein lake and river navigation, practically unrestricted under the treatment proposed, will constitute $128\frac{8}{10}$ miles, or 77 per cent. of the entire passage between the oceans, while the artificial channels will aggregate but 40 miles, or 23 per cent.; and of these artificial channels, 13 miles were to be made so wide and deep as to offer no objectionable restriction, leaving only 27 miles of confined canal, divided into several separate stretches."

Mr. Crowell then proceeded to describe in detail the location of the line, noting the position of the dams, which were to establish the grand summit level of 144 miles in length, and the disposition of the locks; enlarging upon the peculiar conditions to be met in the several cases, and noting the various provisions for control and discharge of surplus water, and for disposing of the surface drainage at the points where the canals required protection therefrom.

He next exhibited drawings of the locks, of which structures there will be seven, three on the Atlantic side, and four on the Pacific, each 650 ft. long, 65 ft. wide, with 29 ft. of water at least depth—these drawings showing fully the various devices provided for working the gates, filling and emptying the locks, the floating moorings for ships, and the constructive features of the lock chambers; the "rolling gate," 88 ft. in height, designed by Mr. Peary, U. S. N., for the great rock-hewn lock, with 53 ft. lift, was fully explained.

The dam structures, of which there are to be two, were described, as also the culverts, waste-weirs, etc., for taking care of small streams encountered at several points.

The breakwater and jetty system, proposed for deepening and protecting from the swell of the sea the canal entrances, were illustrated by means of charts; the author considering that in view of the harbor in Lake Nicaragua for all purposes of through commerce, and the enlarged prisms of the sea sections of the canal, ocean harbors were not necessary, and if constructed, would now constitute a source of superfluous expense. Mr. Crowell here pointed out the causes which had led in the past to the destruction of the once fine sea harbor at Greytown, but claimed that it would be possible to restore it partly, but sufficiently, if, in the future, a necessity for it should arise.

The figures of rainfall, water supply and lockage requirement, were adduced. He stated that the total needs of the canal, to work it to its designed capacity of 32 double lockages per day, would be only $\frac{1}{10}$ of the mean daily flow from the lake, or $\frac{1}{5}$ of the minimum daily flow; and that, in addition to this great surplus of lake supply, the tributary streams would discharge much more than enough water to compensate for leakage and evaporation. The paper concluded with a discussion of the estimate for construction of the entire work, amounting to $65,000,000, including an allowance of 25 per cent. for contingencies—the time required for completing the system ready for service being given at six years—and with a statement of the quality and availability of material for construction to be obtained along the line. The thorough character of the surveys, location and computation were referred to, and the presumptive reliability of the information offered was stated to be exceptionally great.

Mr. Crowell supplemented the discussion by reading extracts from a letter recently published by Mr. Menocal, on the relative costs of operating the Nicaragua Canal and a ship railway, assuming, for the purpose of comparison, the capitalization and volume of traffic to be the same for each; taking the official reports of gross and net earnings of the Suez Canal as the basis for estimating the probable proportion of operating expenses for Nicaragua, and assuming that the operating expenses of the railway, as is claimed by its promoters, would not exceed 50 per cent. of gross receipts; and claimed that the canal under these conditions would earn annually 100 per cent. more than the railway, not taking into consideration the further economic advantages arising from the permanent nature of the canal works, which, if properly constructed, would improve with age, as against the depreciable character of the most expensive parts of the railway and its appurtenances.

Dr. H. M. Chance described some rather paradoxical phenomena experienced in draining a mine by siphons. In the case of a double siphon drawing water from two sumps at different levels, the siphon, upon starting, operated satisfactorily, drawing water from both sumps, but in a few minutes the current in the branch leading to the lower sump reversed, and water was discharged *into* this sump, the main siphon continuing to work as at first. This action seems to be due to the loss of head due to friction, as the water acquires considerable velocity in the discharge by which the efficient head at the lower sump is greatly reduced.

Professor L. M. Haupt deferred his paper on the Delaware Breakwater Harbor until the next meeting, but explained, for the benefit of the members present, a dissected model, showing the condition of the bottom before the breakwater and ice-breaker were built, the position of those structures, the scour and deposits that had occurred, and the work done by the currents in the various zones lying between the several fathom contours. The volumes moved were determined by weight, and important physical results were clearly and intelligibly illustrated. The character of the forces acting in this harbor, were, in the author's opinion, easily and readily determined from the changes which had been produced in the mould of the harbor.

A discussion of the general deductions and remedies was reserved for the next meeting.

RECORD OF REGULAR MEETING, MARCH 6TH, 1886.—The Secretary presented, for Mr. Wm. H. Dechant, a description of a practical test to operate a distant signal by a wire run through a pipe filled with oil.

During last September a distant signal was required to protect a new crossing over the Little Schuylkill Branch of the Philadelphia and Reading Railroad, between East Mahanoy Junction and Tamanend. The distance from the operating office to the semaphore signal post is 1,100 feet, and is part way along a 4 and a 6-degree curve.

Instead of leading the wire through a long wooden box, supported on small pulleys, as is usually done, above the surface of the ground, it was decided to try the experiment of running the wire through a pipe filled with oil, buried below the surface of the ground. A trench, averaging 15 in. in depth, was dug along a carefully laid out line; stakes 8 ft. apart were driven along the bottom of this trench, so that their tops should come to a uniform grade line, which, in this case was about 66 ft. per mile; upon the tops of these stakes the $\frac{3}{4}$-in. galvanized iron pipe was fastened, so as to hold it in as true a position as possible.

A number 15 iron wire was strung through each piece of pipe as they were screwed together, so that it might be used to draw the signal wire through the pipe line after it was all laid. The pipes were all carefully examined and cleaned; a number had to be rejected on account of lumps of iron or galvanizing material obstructing the bore of the pipe. After the pipe was all laid, the $\frac{5}{16}$-in. iron signal wire was stretched out with block and tackle to straighten it and take out all short kinks, and was then pulled through into its proper position in the pipe by the smaller wire that had been strung through during the laying of the pipe; a small brass stuffing box was screwed to each end of the pipe, through which the ends of the leading wire were passed; these stuffing boxes prevent the escape of the oil. The ends of the pipe being thus closed up, it was filled with common car lubricating oil, mixed with about one-quarter part of refined coal oil to keep it from thickening in cold weather; the filling was done through a short upright branch pipe attached at the highest end of the pipe.

The lever, by which the distant signal is operated at the signal office, by the same movement turns four signal boards on the tower, and during the summer the usual counterbalance on the semaphore signal post, adjusted to exert its least weight, would operate the arm on the signal post and revolve the signal boards on the tower; during the colder weather the lubrication is possibly slightly stiffened, so that this same counterbalance barely turns the signal boards in the tower, and must have slight assistance.

The experiment has proved very successful thus far in the severe weather of this winter, and has required no attention since being placed in position.

The apparent advantages of this plan are:

1. A very permanent and lasting arrangement.

2. Freedom from disturbance or accident to the signal wire.

3. Entire freedom from the difficulties caused by expansion, if the pipe is laid below the frost line, and subject to but slight changes caused by change of temperature if laid only one foot under ground.

4. Obviating the necessity to provide angle fixtures to change the direction of the wire around curves.

The difference in cost of materials per 100 ft. is but a trifle, being $5.38 for the pipe plan and $5.42 for the wooden box plan. The difference in labor would depend upon the character of the ground, but in most cases it would be nearly the same.

Mr. J. Foster Crowell exhibited, described, and presented to the Club a model, illustrating the Rolling Lock Gate, designed by Mr. R. E. Peary, Civil Engineer, U. S. N., for the Nicaragua Ship Canal.

Prof. L. M. Haupt continued his paper on Harbor Studies, applying the principles to the harbor of refuge at the Delaware Breakwater. During the past forty years there has been a deposit of over 8,000,000 cubic yards inside the harbor, due chiefly to the checking of the currents by the ice-breaker, which is placed athwart them. The closing of the gap is endorsed, and it is further recommended to remove the ice-breaker, and thus augment the ebb scour. If necessary, floating ice-breakers or caissons may be substituted, but, as a matter of fact, there are but few days in the year when the harbor is encumbered by ice-floes. The damage produced by this structure is very much greater than the benefits it confers. The effects of the breakwater in producing a scour at the gorge, and maintaining a 30-foot channel to deep water—the deep holes scoured by the eddies at the ends of the structure, and the relative costs of various plans, were presented and compared with that of the plan proposed, which it was thought, would produce a much better result at less than one-half the expense. The paper was illustrated by a dissected model explained at the last meeting. The number of wrecks on the Atlantic, between New York and Hatteras, in the past two months, is reported by the Hydrographic Office chart as twenty-two.

Mr. C. W. Pusey described Baird's Distiller, as used in the works of the Pusey and Jones Manufacturing Co., for furnishing distilled water for the men.

Wm. H. Derbyshire described a new double lathe for turning steel-tired car wheels, showing the method of holding the axle at four points, so as to give greater steadiness under the cut. The drivers, adjustable in all directions, and a convenient calipering attachment for bringing the wheels to size, were also shown, as well as the cutting tools, which take the whole face of the tire, including the flange, at one operation.

Mr. F. W. Gordon described a lathe for the same purpose, which resembles, in many respects, the ordinary double-headed wheel lathe. There are two head stocks with face plates, two carriages, etc., for finishing both wheels at the same time. The novel feature claimed for this lathe is the arrangement for supporting the axle on its journals, affording a substantial bearing, close up to the wheels to be turned, and thus permitting heavy cuts and doing true work. The lathe has no live spindles. The

face plates revolve in rigid projections from the head stocks. The only duty of the face plates is to revolve the work, and the trueness of the work is said to be in no way dependent on the fit of the face plate bearings. In these projections are substantial chucks, which grip the axle on its journals. The distance from the point of support to the point of cut is thus reduced to a minimum; the journal support permits a much heavier cut than can be taken in centers; the wheel is turned true. The work, he said can be turned out very rapidly, and, when done, is well done.

The Secretary, for Mr. J. H. Harden, called attention to a publication of the Chesterfield and Midland Counties Institution of Engineers, upon Davis' Self-timing Anemometer.

The Secretary presented the following for Mr. James F. Wood: "The Atlantic City Drainage Company has discovered that many of the pipes were put down at wrong grades, and are now engaged in taking them up and relaying them at proper grades." I enclose above slip cut from Philadelphia paper. The only interest in it is the extraordinary fuss they made in the papers over criticisms of their *modus operandi* at Club meeting last winter.

ENGINEERING NOTES.

Proposed Canal from the White Sea to the Baltic.—The Society for Promoting Russian Trade held a meeting a few days ago at St. Petersburg to discuss the question of joining the White Sea and Baltic by a direct canal *via* Lake Onega. The idea dates back to the time of Peter the Great, who was Russia's greatest canal maker. In point of fact, so comprehensive were that emperor's schemes that there is hardly a project realized since, or still advocated, that does not derive its inspiration from him, even including M. Dru's French scheme for joining the Volga and Don by a canal, and the favorite project of various Russian generals for establishing a waterway between the Oxus and the Caspian. The White Sea is already joined to the Baltic by a long roundabout water route, starting from Archangel and running up the Dwina to point near Vologda. Here canals connect it in succession with lakes Kudensk, Belozersk, Onega, and Ladoga, from the latter of which the River Neva runs into the Gulf of Finland and Baltic. This route, however, is nearly 1,500 miles long, whereas the construction of a canal from Lake Onega to the River Onega, running into the White Sea, or again from Lake Onega to Vigozera Lake, and thence into the White Sea, would reduce the distance to nearly one-third. The cost of the proposed canal would be about 7½ million roubles, or £750,000; it would be large enough to allow barges over 100 ft. long and correspondingly wide to traverse it with ease. Of late years commerce has decayed very much in the White Sea, owing to the growing tendency of the Russian population to move south to the Euxine, and the general indifference of the Government to the north. Formerly Russia maintained a large fleet in the White Sea, but the navy was totally abolished a few years ago. If the proposed canal were constructed, it is believed by the Society for Promoting Russian Trade that commerce would revive, and that an impulse would be given to the iron industry of the Onega region. Last year, to appease the clamor that the Moscow press had raised at the decay of Russian power in the north, the Czar sent the Grand Duke Vladimir to visit the White Sea, and the promoters of the canal scheme are endeavoring to take advantage of this to secure the support of the authorities. However, seeing the large number of railways and other public works sanctioned this year, we question whether success will attend their efforts.

Herren Bleininger and Hasselmann, two German chemists, have described a method of making facing materials for inner walls likely to become damp. After drying and grinding the clay, they make a mixture of clay, 91½ parts; iron filings, 3 parts; common salt, 2 parts; potash, 1½ parts: elder or willow wood ashes, 2 parts. The whole is heated to a temperature varying from 1,850 to 2,000 deg. Cent.—3,362 to 3,632 deg. Fah. At the end of from four to five hours the argillaceous mixture is run into moulds, then re-baked in the ovens—always protected from the air—at a temperature of 842 to 932 deg. Fah. The product may be variously colored by adding to the above 100 parts: 2 parts of manganese for a violet brown, 1 part of manganese for violet, 1 part of copper ashes for green, 1 part arseniate of cobalt for blue, 2 parts of antimony for yellow, and 1½ parts of arsenic and 1 part oxide of tin for white. The *Scientific American* says these products resist the action of acids, and are well adapted for sewers, etc.

IRON AND STEEL NOTES

On the Construction of Tungsten and Iron Alloys.—The following investigation was made with a view of determining the chemical constitution of the compounds of iron and tungsten, employed in steel-making. An alloy of the specific gravity 9.31, containing iron 68.4, tungsten 28.2, and carbon 1.9 per cent, was closely powdered and boiled in hydrochloric acid until the evolution of hydrogen ceased, when the crystalline powder adhering to the surface of the fragments was rubbed off. The metallic powder obtained from several repetitions of the above operation was boiled for several hours in hydrochloric acid, and finally washed with water, boiling potash lye, alcohol, and ether, and heated to redness in a current of hydrogen. The result was about 40 per cent. of metallic residue made up of two alloys, separable by the magnet, while scarcely a trace of tungsten was dissolved. The larger part of this residue—fully 90 per cent.—consisted of light steel-gray grains, perfectly unmagnetic, which are well-formed octahedral crystals, sufficiently hard to scratch glass, but so brittle as to be easily rubbed to powder in an agate mortar. They contain iron from 24 to 31, tungsten 69,83, and carbon 1.4 to 1.6 per cent. When heated in the air the powder burns with a glimmering light to a brown, non-magnetic product, which, when heated in hy-

drogen, is reduced to tungsten iron, the crystals preserving their form. No iron is extracted by boiling hydrochloric acid.

In order to compare the behavior of this iron alloy with those with other metals, a perfectly unmagnetic ferro-manganese, containing iron 35, manganese 57.6, and combined carbon 5.87 per cent,, was powdered, and oxidized by heating in the air. This was attended with the production of magnetic oxide of iron rendering the whole of the powder magnetic, and after reduction in hydrogen, metallic iron could be separated by the same means. The effect of tungsten in modifying the chemical properties of iron when diffused through it, is very marked. This in the particular alloy under examination was found to be completely unaffected by a solution of chloride of copper.

From their microscopic characters, as well as their low specific gravity—3.688—it is evident that the crystals, in spite of their compact appearance, are actually hollow forms inclosing gases. The magnetic portion of the residue is a blackish grey metallic powder, without distinct crystalline character. It contains iron 68.1, tungsten 27.7, and carbon, 4.1 per cent When heated in air it burns, augmenting about 80 per cent. in weight, and remains magnetic By heating in hydrogen, a tungsten—iron compound—is reproduced, which readily gives up iron by digestion with hydrochloric acid.

The same alloys were obtained by boiling hydrochloric acid from a pig iron, containing 23.5 per cent of tungsten; but the proportion of the magnetic uncrystalline compound is larger than that of the harder tungsten crystals. A highly carburized tungsten steel, containing tungsten 11, manganese 1.49, and carbon 2.15 per cent., gave, on solution in hydrochloric acid, 13.1 per cent. of residue in the form of a fine unmagnetic powder similar in composition to the crystals previously described, while a soft steel, containing tungsten when digested with dilute acid, only left traces of iron containing tungsten. The general conclusion drawn from these experiments is, that tungsten is not actually alloyed with the iron, but exists essentially in a free state diffused through the mass of the softer metal, and preserving its own characteristic properties. The most notable of these, namely, low specific volume, accounts for the circumstance that, in order to produce very hard steel by tungsten, it must be used in considerable quantity, in which respect it is in marked contrast to other hardening agents, such as carbon and phosphorus, which form chemical combinations with iron.

RAILWAY NOTES.

The complaints which have been made against the use of steam on the Birmingham tramways are directing attention once again to the reputed superiority of the cable system. A correspondent in a Birmingham newspaper points out that in San Francisco there are six cable lines covering all the most crowded thoroughfares in the city. The cars ascend steep gradients, as much, in some cases, as 78 ft. in 412 ft., and they turn around corners and even cross each other on the same level without any difficulty. In Chicago, also, the efficiency of the system has been amply demonstrated. In that city there are ten miles of double track, and it is worked from one engine house, where there are four engines of 2,000 horse-power in the aggregate; but only one-quarter of this power is ordinarily used, and this operates 270 cars.

Chinese Railways.—English, American, Belgian, French and German industrials all have their eyes directed upon China just now as a profitable field for railway enterprise. A French syndicate has been formed by the Fives-Lille Company and the bankers who group themselves round the Paris Comptoir d'Escompte. M. de Freycinet has instructed French agents in China to afford this syndicate all possible aid. The indefatigable Krupp, of Essen, the Dortmund Steel Works Company and the Deutsche Bank have formed a German syndicate, which Prince Bismarck will support with all the resources of German diplomacy. An American syndicate has been formed under the auspices of the house of Jardine, Matheson & Co., which is very influential at Pekin. The first line proposed to be taken in hand will run from Nankin to Pekin, and will be about 690 miles in length. A second line in contemplation is one from Canton to Honoi, about 562 miles long. We shall probably hear of a heavy Chinese railway loan before long.

ORDNANCE AND NAVAL.

Important Armor-Plate Tests.—An important test of compound armor was made on January 21, on board the Nettle, at Portsmouth. The plate was manufactured on Ellis' compound system, by Messrs. John Brown & Co., Sheffield, and was a sample of a number which are now being made by them for the belted cruisers Orlando and Undaunted, now building at Messrs. Palmer's, on the Tyne; the Australia, building at Messrs. Napier's, on the Clyde, and the Narcissus, building at Messrs. Earle & Co 's, Hull. The plate measured 6 ft. by 8 ft., and was of a total thickness of 10 in. It was fired at by the 10-in. gun, with a Palliser shot of 400 lbs. and 70 lbs. of pebble powder. Notwithstanding the severity of the test, the plate withstood the ordeal very successfully. The deepest indent was not thought to be more than about 5 in. The first and second rounds produced circular cracks, probably extending to the depth of the steel around the points of impact, and a few hair cracks on the surface. The third and final shot produced a crack to the right edge of the plate, which, on subsequent examination, was seen to be through, but only $\frac{3}{4}$ in. in the widest part. A remarkable feature was that the bulges at the back of the plate were unprecedentedly slight—only from $1\frac{1}{8}$ in. to $1\frac{1}{2}$ in high—and that they were entirely free from cracks, as was also all the back of the plate, with the exception of the above-named crack to the right edge.

A New Armor-Plated Ship.—The first steel plates of a new armor-plated turret ship, to be called the Trafalgar, a sister ship of the Nile, which is to be built at Chatham, have

been laid down at Portsmouth. The pieces of keel consisted of the central flat and vertical plates, forming the basis on which the whole structure of the vessel will rest. The flat keel is in two thicknesses, the lower or outer one being $\frac{3}{4}$ in. thick, and the inner one $\frac{1}{2}$ in., the vertical keel being also of the latter thickness. This latest development in armorclad construction will resemble the Dreadnought in many important particulars. To say that she is an improved Dreadnought will signify little more than that she is a turret ship, that her turrets are built across the middle line of the ship fore and aft, that she will carry larger guns and thicker armor, and, as a matter of course, that she will have greater dimensions, in order that this accession of weight may be floated. So far as her profile is concerned, she will more closely resemble the vessels of the discredited Admiral class than the early turret ships; but, as a matter of fact, the Trafalgar is the first of a distinctly new type of protected fighting ships, and combines modifications of the special features of the Dreadnought and Collingwood class. Take away the barbettes of the latter, and replace them by movable turrets, with a water-line armor belt, and something closely resembling the Trafalgar will be the result, or, to put the subject another way, add a superstructure battery between the turrets of the former, and a rough idea of the new ship will be acquired, differences of size being allowed for. The Dreadnought has a length of 320 ft., and breadth of 63 ft. 10 in., and a displacement of 10,820 tons; while the length of the Camperdown is 330 ft., her breadth 68 ft. 6 in., and her displacement 10,000 tons, the difference of the tonnage being due to the difference in the amount of side armor. As the Trafalgar, on the other hand, is not only intended to carry as powerful guns as the Camperdown, but to be protected by an armored belt, her bulk is necessarily greater than either. In length she will be 345 ft., while her beam will be 73 ft., her mean draught 24 ft., and her displacement 12,000 tons, so that she will be a larger ship than the Inflexible, which is 320 ft. long by 75 ft. broad, with a displacement of 11,400 tons. What engine-power she will possess is not known, as the tenders have not yet been prepared, but she will be fitted for forced draught, and it is expected that she will realize a speed of 18 knots. She will be protected by broadside armor 20 in. in thickness, consisting of steel-faced plates, and this armor, while extending nearly the whole length of the ship, is much deeper than in vessels of the Admiral class. In modern turret ships, the turrets are placed diagonally at opposite corners of the citadel, so as to obtain a simultaneous fire of all the guns ahead or astern, unobstructed by the light superstructures at the ends. In the Trafalgar, there will be no forward and after superstructures, and the turrets, which are to be 18 in. in armored thickness, being built at the middle line at each end of the citadel, will have the advantage of practically unlimited training ahead and astern. These turrets will, of course, be able to fire either directly ahead or directly astern together, but with the great increase which has taken place in the power of the guns the advantage which the battle ships of the Colossus class possess in this respect is more apparent than real. The fore turret will have a range of 45 degrees abaft the beam. and the after turret a range of 45 degrees before the beam, giving each a training arc of 270 degrees. As regards the disposition and range of her turrets, the new ship resembles the Dreadnought, but she differs from her prototype in having a central battery between the turrets carrying eight 5-in. breechloaders, having a fair amount of protection, and a superstructure above, which, together with the battery, extends out to the full breadth of the ship, and on which will be mounted a number of rapid-firing 6-pounder and machine guns. Each turret will contain a couple of 66-ton breechloading rifled guns, for which the weight of charge and projectile has not been settled. The torpedo equipment will be unusually large, as many as seven positions having been appropriated for discharging the Whitehead torpedo. Four will be under water, one at the bow, and the remainder above water on the broadside. It is confidently expected that the Trafalgar, when completed, will be the most formidable armorclad either in our own or in any foreign navy. Some delay has occurred through a want of material, but it is believed that the vessel will be ready for launching in about two years. Four years will probably elapse, however, before she will be ready for the pennant.

BOOK NOTICES

PUBLICATIONS RECEIVED.

EXTRACTS from the Report of the Director of the United States Geological Survey:

——— The Requisite and Qualifying Conditions of Artesian Wells. By Thomas C. Chamberlain.

——— The Topographic Features of Lake Shores. By Grove K. Gilbert.

BULLETINS of the United States Geological Survey:

No. 15.—The Mesozoic and Cenozoic Paliontology of California.

No. 16.—The Higher Devonia Faunas of Ontario Co., New York

No. 17.—The Development of Crystallization in the Igneous Rocks of Washoe, Nevada.

No. 18.—On Marine Eocene, Fresh Water Miocene and other Fossil Mollusca of Western North America.

No. 20.—Contributions to the Mineralogy of the Rocky Mountains.

No 21.—The Lignites of the Great Sioux Reservation.

No. 22 —New Cretaceous Fossils from California.

No. 23.—On the Junction between the Eastern Sandstone and the Keweenaw Series on Keeweenaw Point, Lake Superior.

NEW Ordnance Material and Armor Material in Europe. By Captain William Bixby. New York: *Engineering News* Pub. Co.

LITHOGRAPHIC Chart of Iron and Steel Beam Sections of the New Jersey Steel and Iron Co.

REPORT of the Operations of the Engineer Department of the District of Columbia. Washington: Government Printing Office

PROCEEDINGS of the Institution of Civil Engineers:

Paper No. 2070.—On the Theory of the Indicator and the Errors in Indicator Diagrams. By Osborne Reynolds, LL. D., F. R. S.

Paper No. 2107.—High Speed Motors. By John Imray, M. Inst. C. E.

Paper No. 2108.—On Construction in Earthquake Countries. By John Milne, F. G. S.

SCHOOL ELECTRICITY. By J. E H. GORDON, B. A. London: Sampson Low, Marston, Searle & Rivington.

The object aimed at by the author is thus stated in the brief preface: "The object of the present work is to give schoolboys a knowledge of electricity, which, however incomplete, shall be of a useful kind.

"For this purpose the work commences with the study of electric currents and Ohm's law, and the teaching is of the same kind as that which I have been in the habit of giving to members of my staff and to men employed in electric light work. At the same time I have given such details of theory as will, I hope, show students that a science of electricity exists, and stimulate them to study it. I have further endeavored to show the intimate connection which exists between electricity and light, heat and mechanical energy."

The book will be found to be an easier introduction to practical electrical work than are most of the text books now in use. To adapt it to the instructor's use, questions are appended to each chapter. It is just such a book as eager inquirers have been demanding for the past two or three years.

ELECTRIC RAILWAYS AND THE ELECTRIC TRANSMISSION OF POWER DESCRIBED IN PLAIN TERMS. By ROBERT LUCE, A. M. Boston: W. I. Harris & Co.

This description in popular language of an important class of inventions will prove satisfactory to a large class of readers. Divested of mathematical formula and of technical terms, except such as are absolutely indispensable to an understanding of the general principles, the book will satisfy a demand which is constantly made for an elucidation of these principles which can be read without laborious study.

The Electric Transmission of Power, the History of the Electric Railway, Electric Railways Abroad, Electric Railways in America, Cost of Electricity, Electricity on Elevated Roads, and Telpherage, are treated successively, and with satisfactory clearness and conciseness.

THE PRACTICAL MECHANIC'S WORKSHOP COMPANION. By WILLIAM TEMPLETON. An entirely new edition revised and enlarged. By WALTER S. HUTTON, C. E. London: Crosby, Lockwood & Co.

The general scope of this book is too well known to require special mention here. The new material relates to Air, Gas, Water, Heat and Steam; Testing Engines and Boilers, Turbines, Strength of Materials, Gearing, Chimneys, etc.

Besides the numerous tables which are always found in such handy collections, this book contains fairly complete treatises on Practical Trigonometry and Orthographic Projection.

DIE PRATISCHE ANWENDUNG DER SCHIEBER UND COULISSENSTENRUNGEN. Von WM. S. AUCHINCLOSS. Berlin: Julius Springer.

This is a translation into German of Auchincloss' treatise on the Slide Valve and Link-Motion. The plates, cuts, and typography are exceedingly good.

TABLES FOR CALCULATING THE CUBIC CONTENTS OF EXCAVATIONS AND EMBANKMENS. (Second edition.) By JOHN R. HUDSON, C. E. New York, John Wiley & Sons.

The range of these tables is made to include widths of road-bed from 10 ft. to 28 ft., and center heights to 50 ft.

The previous edition had become favorably known to engineers for convenience of form and correctness in the results obtained by their use.

VORTRAGE UBER BRUCKENBAU.—Part I. Von DR. E. WINKLER. Vienna: Carl Gerold's Sohn

This work of Dr. Winkler will be gladly welcomed by all engineering students who can read German. The author has been for a long time considered an authority upon all subjects relating to engineering structures, and particularly upon the controverted questions relating to complex framings, continuous girders, and the like.

The present edition is the third. The first appeared under the title of "Theorie der Brücken."

The first part only of the new edition is represented in the present volume, and the discussion is limited to the "external forces" acting upon girders.

Of the three sections into which it is divided, the first, A, deals only with "stationary" and "fi ted" loads, on simple girders and on overhanging girders.

Section B, which is the greater part of the book, treats of continuous girders, giving both the analytic and graphic discussion of girders of two, three, four, and, finally of many spans.

Section C treats of bending moments and change of form.

The illustrations are plentifully distributed through the text, and six lithographic plates are placed at the end of the volume. The whole is exceedingly well printed, but upon rather thin paper.

MISCELLANEOUS.

THREE tall chimneys belonging to Kunheim & Co., of Berlin, were lately destroyed by means of gun-cotton. The largest was about 147 ft. high, and 10 ft. diameter at the base. In order that it should fall outwards from the city, the charge of guncotton—about 57 lbs.—was attached in portion to the side next the city, and to the adjacent sides. All three were exploded simultaneously with a magneto-electric apparatus. The chimney, instead of falling obliquely, collapsed vertically, and, on inspec-

tion, the four walls of the pedestal were found to have been driven outwards. The bricks were all detached from each other, and nearly all entire, *Nature* says the *debris* was thrown a very little distance. The two other chimneys, treated similarly, fell as was expected, *i. e.*, obliquely away from the city. One of them, in falling, broke in two about the middle.

EMERY MINES OF ASIA MINOR.—Although emery stone is found in nearly all parts of Asia Minor, and not unfrequently in the remote and almost inaccessible regions of the interior, where the natural obstacles are too great to offer any inducement to the miner, the principal mines are confined to the districts of Thyra and Aidin. These mines, says Consul Stevens, of Smyna, are the Tchavus, the Hassan Tchavuslar, the Aladjali-Tchiflik and Kourchak, the Halka, the Akdere, and the Gurnush Dogh, There is another mine near Millassa, the stone from which is brought for shipment to a place on the coast called Kuluk, near the Gulf of Mendalio, and is either shipped direct from that place to foreign markets, or brought to Smyrna in small sailing craft for reshipment. When well picked and freed from unsound ore and rubbish, the emery from the Tchavus, Hassan Tchavuslar, and Aladjali-Tchiflik mines is of good and nearly equal quality. The Akdere stone is not so much sought after, while that excavated near Milassa, the larger part of which finds purchasers in the United States, is of inferior quality, the grain being smooth, and a considerable quantity of magnetic iron entering into its composition. The amount of stone annually shipped from Smyrna to Great Britain, the United States, France, Germany, and Belgium, averages 7,000 tons, the relative quantity consumed in each country being in the order named. The process of extraction is as follows: The mines are opened by wells and galleries, and the stone is obtained in most instances by blasting, gunpowder and dynamite being freely used to extract it from between blocks of marble or masses of granite. The overseers and principal workmen at the mines are Italians, who are paid at the rate of three shillings and sixpence a day, while the native workmen only receive about half this amount. The emery is picked daily at the mines as fast as it can be extracted, in some cases not one-half the quantity being selected. It is then conveyed by camels to the nearest railway station, and from thence to Smyrna, where it is generally picked again previous to shipment. When the mines are situated on heights inaccessible to camels, the ore is brought down to the plains by donkeys, and if the pieces are too large to be carried by camels, they are brought to the station in carts drawn by buffaloes. The mines are worked upon the strength of concessions termed *firmans*, granted by the Imperial Government for a period usually of ninety-nine years, or, in cases where the emery has been found on *nacouf* property, that is property belonging to the Turkish religious institutions, by special permit of the department at Constantinople which administers the *nacouf* estates, and exacts payment to them of so much per quintal. A *firman* or concession during the period it is in force can be sold, transferred and transmitted by inheritance, like other property in Turkey, provided due notice be given to the Department of Mines at Constantinople, and authorization formally obtained.

SNOW IN CITIES.—Paris spent about 220,000f. in clearing away the snow of the 8th and 10th of December last, when the fall amounted to from about 8 to 10 centimeters, or, say, 3 in. to 4 in., and from 6 to 8 centimeters, or from 2¼ in. to 3 in About 125 grammes of salt were used per square meter, and is said to cost but little in the total, while it makes a great reduction in the cost of removal of a snowfall. The objections which are made in London against the use of salt are, however, real, the low temperature of the mixture doing much harm to horses. In London, during the snowstorm of the first week of January, some sharp work was done under considerable difficulties. The snow began to fall as early as six o'clock on the Wednesday morning, and continued till past twelve, and the principal streets had to be cleansed three times that day. A sharp frost set in subsequently, and in that the Commissioners' trouble consisted. Since the last great storm, five years ago, a vast amount of wood paving had been laid down, and it was very difficult to remove the frost from it. Asphalte, on the contrary, could be thoroughly cleansed in three hours. The committee employed, in the removal of the snow, 1,139 extra laborers, and 1,077 extra carters, besides their ordinary staff of 500 men and 61 dust-sifters and wharfmen; they used six barges and 1,777 horses and carts, and sprinkled in the streets 7 tons of agricultural salt, and altogether they removed from the streets 6,000 loads of snow. In 1881 they had large vacant spaces on which they could temporarily deposit the snow—in Petticoat Lane, on the Thames Embankment, and in Golden Lane; but these sites were now occupied, and they had to cart the snow to Finsbury Circus, Smithfield, and Letts' Wharf. On the whole, the work was wonderfully well done, and though some of the side streets, with little or no traffic, had been left to the last, it was inevitable that, in so exceptional a state of things, some little inconvenience must be endured. Regent Street was for days a disgrace to the borough surveyor and the vestry. The highways committee of the Islington Vestry did a good deal, but they have a large area to work; 400 men, besides the regular staff were engaged in the work. These were reinforced by sixty able-bodied men from the Islington Workhouse, and on the Monday 640 laborers were employed, in addition to the ordinary scavengers Between Wednesday the 6th, and Saturday the 9th inst., the snow was cleared in twenty miles of roadway and stacked in heaps at the sides. This represented the displacement of over 80,000 cubic yards of snow, and by the Wednesday the snow had been virtually cleared from the entire length of the roadways of the parish. Of the snow which had been stacked in heaps, the dusting and slopping departments had carried away 4,545 loads, or 9,027 cubic yards. The total expenditure incurred in connection with the work, exclusive of cartage was estimated by the surveyor at £815.